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ON THE COLOURS OF INORGANIC SALTS

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There have been many diverse opinions regarding the origin of colours shown by inorganic salts in the solid state, and in solution. A short summary is given in the 'Handbuch der Physik,' Vol. XXIV, p. 564. According to Hoffmann and his co-workers colour is shown only by compounds of such elements which show a varying valency such as Fe, CO, Ni ... Ladenberg made the first attempt to connect colour with atom-structure. He showed from analysis of existing data that colour is almost invariably shown by salts of elements belonging to transitional groups (Sc to Cu) and rare-earths, and very seldom by salts of elements belonging to regular groups. Compounds like NaCl, MgCl₂, AlCl₃, SiCl₄ ... show no colour, while chlorides of all the elements of the transitional groups (Sc to Cu) show colour. Ladenberg tried to define the electron transition responsible for colour in the following way. He pointed out that in elements from Sc to Cu, the 3d-shell is being formed and there are some electrons in the 4s-shell. He points out that there is some sort of competition between the 3d- and 4s-shells for the possession of electrons, and hence light of very small energy (visible)

may be able to effect transition of the electron from any one of these two levels to the other, *i.e.*, from $3d \rightarrow 4s$.

Meisenheimer showed that the nature of the anion also has some influence on the colour. Fajans attempted to connect colour with deformation of the cation, produced partly by the anion. He points out that CuF_2 and CuSO_4 (anhydrous) are colourless, and hence concludes that the Cu^{++} -ion must be colourless, but in aqueous solution as well as in ammoniacal solutions Cu^{++} -ion gives a blue colour. This is ascribed to some deforming action of H_2O or NH_3 molecules on the Cu^{++} -ion.

The question of colour forms part of the larger question of binding of atoms of different types to form aggregates of different orders, *e.g.*—molecules, crystals, solutions; and light is thrown on the problem from many directions, *viz.*, from consideration of the course of refractive index for solids, magnetic properties, or spectral absorption for solids and gases, etc., etc. . . . , and investigation of the same properties in the case of solutions. Pauli's principle has given us the rule governing the formation of atoms out of nuclei and electrons, but the exact way in which it will have to be modified in formation of molecules and more complex aggregates is not yet known to the satisfaction of the theoretical physicist.

In a note published in 'Nature,' Vol. 125, page 163, one of the authors tried to show that the colours of the salts of the transitional groups may be ascribed to the electrons of the d-shell, but not in the way imagined by Ladenberg. If we take a compound like CrCl_3 , we may suppose that the

picture of the combination is given by $\left[\text{Cr}^{+++} \right] \begin{matrix} \text{Cl}^- \\ \text{Cl}^- \\ \text{Cl}^- \end{matrix}$. Thus there

are three chlorine ions surrounding the Cr^{+++} nucleus. That this assumption corresponds to the actual picture is almost guaranteed by magnetic properties of CrCl_3 . The paramagnetic susceptibility of trivalent chromium compounds is almost entirely due to the Cr^{+++} ion, the Cl^- ion contributing nothing to the magnetic moment. Hence the colour must be due

to the reaction of light either on the electrons or on Cl^- ions. But we know that the absorption of the Cl^- ion in the vapour state is in the ultraviolet below $\lambda 3000$, and hence visible light will be without action on the Cl^- ions. Hence colour arises from the reaction of light on Cr^{+++} ions. This contains, in the free atomic state, an incomplete d^3 -shell, giving rise to ${}^4\text{F}$, ${}^4\text{P}$, ${}^2\text{H}$, ${}^2\text{G}$, etc., terms. What will be the nature of these levels in a compound?

Light is thrown on this question from consideration of the magnetic moment of the Cr^{+++} -ion. If, following Hund,¹ we suppose that the electrons of the d^3 -shell are bound with the usual 'l' and 's' coupling which gives us the fundamental terms of the Cr^{+++} -atom, the magnetic moment cannot be explained. Prof. D. M. Bose² showed empirically that the magnetic moment is explained if we suppose that only the 's'-coupling is operative and the 'l'-coupling breaks down in compound formation. Stoner³ has given theoretical justification for this assumption, and explained many other anomalous cases. The breaking of 'l'-coupling can be inferred also from our present knowledge of molecular spectra, where we find that the 'l' vectors of outer electrons get subdivided along the line of binding of the component nuclei while the 's' vectors take up either the parallel or the anti-parallel directions. We can therefore suppose that the action of light consists in changing the spin of one of the component electrons in the d^3 -shell. The energy required for this process may be inferred. In the gaseous state, Cr^{+++} -ion gives rise to the following terms:—

$${}^4(\text{P F}), {}^2(\text{P D F G H}), {}^2(\text{D}).$$

Cr^{+++} atom is partially analysed by White and some of the term values are known. They are given in Table I.

The difference in value is of the order for the absorption of visible light not only in Cr^{+++} , but as can be seen from the table, (Table II), in almost all ions of the elements of the transitional group.

Table I—Terms of d^3 elements

Term Elements	$4F$	$4P$	$2H_{5,6}$	$2G_{7,5}$	$2D_{3,1,2}$	Reference
Sc						
Ti ⁺	0	8965	11769 11867	8190 8210	11721 11851	H. N. Russell, Astro. Journ., 66, 288 (1927)
V ⁺⁺	0	11513	16822	• 11966	16229	H. E. White, Phy. Rev., 33, 674 (1929)
Cr ⁺⁺⁺	0	...	21027 21278	15014 15371	...	H. E. White, Phy. Rev., 33, 676 (1929)
Mn ⁺⁺	0	...	24395 25361	17852 18468	...	H. E. White, Phy. Rev., 33, 679 (1929)

Table II—Difference between the highest and the next term
with lesser-multiplicity

Stage of Ionisation Elements	II	III	IV	V
Sc				
Ti	11800	14500		
V		16800	19087	
Cr			21000	23237
Mn				25000

[II, III, IV, V denote first, second, third and fourth state of ionisation.]

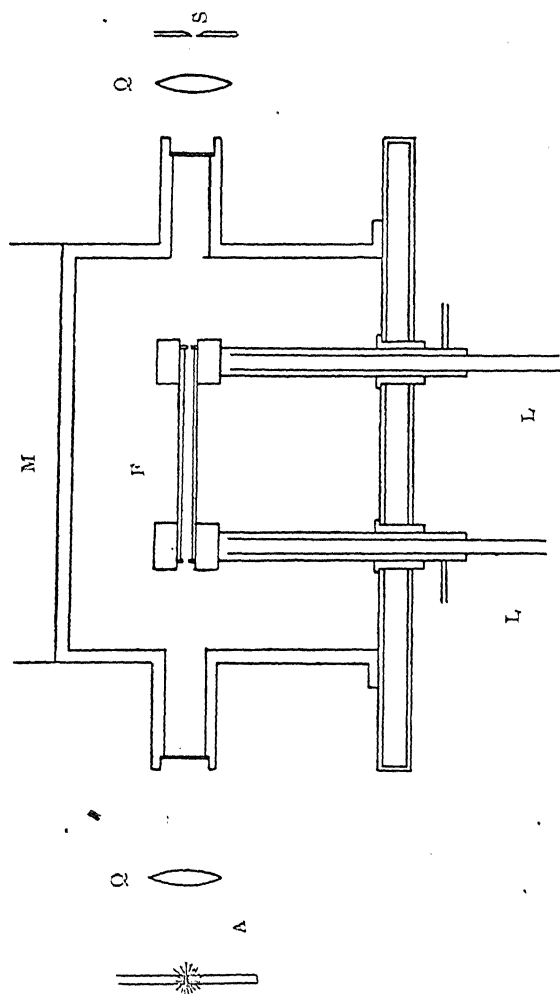


Fig. 1. F—Furnace, M—Iron mantle, Q—Quartz lens, A—Under water copper spark,
L—Leads for heavy current, S—Slit for spectrograph.

A number of experiments can be designed to test this hypothesis. Owing to the limitations of this laboratory we undertook investigation of the absorption spectrum of a few chlorides of the transitional group.

Experimental Procedure

We chose as our first experimental material CrCl_3 . This is obtained in pink-coloured scales, and according to information obtained from standard treatises on Chemistry, it forms a stable vapour at $1200^\circ\text{--}1350^\circ\text{C}$, whose vapour density corresponds to the formula CrCl_3 . It does not decompose up to a temperature of 1500°C .

It is a vacuum furnace of acherson graphite used in this laboratory for experiments on the thermal ionisation of elements. The CrCl_3 was placed within a silica tube which was placed within the furnace. This was to prevent direct contact of the carbon of the furnace with CrCl_3 . The ends of the furnace were plugged with iron rings leaving only narrow opening in the centre for passage of light. These rings prevented quick outflow of hot vapour. The evaporation of CrCl_3 is so rapid that the whole mass disappears before any exposure can be given. When the furnace is filled with N_2 the conditions could be kept steady.

Source of continuous light was an under water-spark between two copper electrodes. The rays from the spark were made parallel with a quartz lens and allowed to pass through the furnace over the hot vapour of CrCl_3 , and on emergence again focussed on the slit of an E₁ quartz spectrograph, kindly lent to us by Prof. N. R. Dhar of the Chemistry Department. Copper arc was taken as comparison spectrum. The spectrum was examined between $\lambda 5000$ to $\lambda 2400 \text{ \AA}$.

Absorption bands were obtained in the blue-violet region extending slightly into the ultraviolet. They were analysed and are seen to form two distinct systems which we depict below by A and B systems. Following is the analysis of the bands:

Table III—System A

$\begin{smallmatrix} v'' \\ v' \end{smallmatrix}$	0	1	2	3	4
0	22654.5	22241.7	21828		
1	23067	23652	22236	21824	
2	23477	23062	22646	22232	21822
3	23883	23472	23059		
4		23874	23468	23054	
5			23869	23462	

This system of bands can be represented in the following formula:

$$\nu_{\text{head}} = 22654.5 + (414.07v' - 87v'^2) + (414.2v'' - 60v''^2)$$

The second system of bands which we designate by "System B" is given below:

Table IV—System B

$\begin{smallmatrix} v'' \\ v' \end{smallmatrix}$	0	1	2	3
0	22545.1	22117	21689	
1	22958	22525	22093	
2	23352	22926		
3	23741	23318	22907	
4		23699		

The above set of bands is also represented in an empirical formula which we give below:

$$\nu_{\text{head}} = 22545.1 + (414.0\nu' - 4.7\nu'^2) + (431.2\nu'' - 3.65\nu''^2)$$

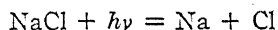
In addition to these band absorptions, continuous absorption was obtained near λ 3000 Å. U., and the spectrum is completely cut off at λ 2700 Å. U.

Table V—List of absorbed band heads

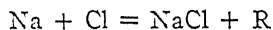
λ	$\nu(\text{vac})$	System	Classification $\nu'' \rightarrow \nu'$
4185.8	23883	A	0—3
4187.4	23874	A	1—4
4188.3	23869	A	2—5
4210.7	23742	B	0—3
4219.4	23699	B	1—4
4258.25	23477.2	A	0—2
4259.2	23472	A	1—3
4260.0	23468	A	2—4
4260.9	23462	A	3—5
4280.8	23352	B	0—2
4287.3	23318	B	1—3
4333.88	23067.5	A	0—1
4334.9	23062	A	1—2
4335.5	23059	A	2—3
4336.4	23054	A	3—4
4354.3	22958	B	0—1
4360.6	22926	B	1—2
4364.2	22907	B	2—3
4412.90	22654.5	A	0—0
4413.39	22652.1	A	1—1
4414.5	22646	A	2—2
4434.34	22545.1	B	0—0
4438.2	22525	B	1—1
4494.80	22241.7	A	1—0
4495.9	22236	A	2—1
4496.8	22232	A	3—2
4520.0	22117	B	1—0
4525.0	22093	B	2—1
4580.1	21828	A	2—0
4580.9	21824	A	3—1
4581.3	21822	A	4—2
4609.3	21689	B	2—0

Discussion of the Results

A large amount of work has been published on the absorption spectra of the halides. Two types of absorption have been found. In the case of saturated halides of alkali elements only a continuous absorption is obtained. Franck, Kuhn and Rollefson⁴ have shown that the beginning of absorption corresponds to the photodissociation of the halide-molecule into constituent atoms:



ν corresponds to the atomic heat of dissociation:—



R is calculated from a Born-cycle. We have

$$R = Q + L_{\text{Na}} + \frac{1}{2}D_{\text{Cl}_2} - L_{\text{NaCl}} \quad \dots \quad (1)$$

where Q =heat of formation of solid NaCl out of solid Na and Cl_2 gas, L_{Na} is the latent heat of evaporation of Na, D_{Cl_2} is the heat of dissociation of Cl_2 , and L_{NaCl} is the heat of evaporation of NaCl.

Franck has shown that most alkaline halides give the same kind of results as NaCl; he assumes that in these compounds, the valency electron of Na passes over to Cl, thus the binding is electrostatic, due to attraction between Na^+ and Cl^- or polar. When light falls on an NaCl-molecule, the electron in Cl^- passes on to Na^+ — thus resulting in dissociation of NaCl to neutral Na and neutral Cl.

But there are other chlorides like HCl^* which show a continuous absorption, but the beginning of absorption does not correspond to the heat of formation of HCl out of H and Cl.

A second class of chlorides like AgCl^* , ThCl^* , etc., shows band absorption in addition to the continuous absorption. The band absorption in such cases has not been satisfactorily explained.

Very little work has so far been done on the band-spectra of polyatomic halides, but a few experiments have been carried

out in this laboratory (*vide* papers by A. K. Dutt and M. N. Saha, S. C. Deb and H. B. Mohanti). It appears from these works that all saturated halides like MgCl_2 , AlCl_3 , ... show only continuous absorption, and if ν denotes the frequency of the beginning of absorption

$$h\nu = \frac{R}{n}, \quad \dots \quad (2)$$

where R =heat of formation of the gaseous molecule out of constituent atoms, n =valency.

$$R = Q + L_M + \frac{n}{2} D_{\text{Cl}_2} - L_{\text{MCl}_n} \quad \dots \quad (3)$$

On the other hand, it appears that non-saturated halides like CrCl_3 , as well as halides of Ca, Sr, Ba (*vide* forthcoming paper by S. C. Deb and B. Mukerji) give, in addition to continuous absorption, well marked band absorption. The continuous absorption seems to be due to the splitting up of a Cl-atom from the molecule. We may try to find out when (3) holds in the case of CrCl_3 in absorption. We have

$$R = Q + L_{\text{Cr}} + \frac{3}{2} D_{\text{Cl}_2} - L_{\text{CrCl}_3} \quad \dots \quad (4)$$

Q , the heat of formation of $[\text{CrCl}_3]$ out of $[\text{Cr}]$ and Cl_2 , is about 145 kcal, but neither L_{Cr} nor L_{CrCl_3} is known. Hence (4) cannot be tested.

Band Absorption

The band absorption of CrCl_3 is certainly due to the reaction of light on the d^3 -shell of the Cr^{+++} -ion. As is known from theories of complex spectra, the spin moments of all the electrons in the normal state for the d^3 -shell are parallel giving rise to a 4X -term ($X = F, P \dots$ when Pauli's principle is operative). The action of light would be to turn the spin of one of the electrons in the opposite direction giving us a 2Y -term. Thus the magnetic moment of the Cr^{+++} -ion on light absorption will be changed from $\sqrt{4S(S+1)} = \sqrt{4 \cdot \frac{3}{2}(\frac{3}{2}+1)}$, i.e., from $\sqrt{15}$ to $\sqrt{3}$, i.e., will get changed by about 2.5 times per quantum absorbed. The effect has been qualitatively found by Prof.

D. M. Bose,⁸ but contrary to expectation, the magnetic moment of CrCl_3 solutions is found to increase on illuminations by light which can be absorbed. Prof. D. M. Bose is of opinion that the increase is due to the supposed fact that the coupling of the d-electrons of the paramagnetic ions with the associated water molecules, known as l-coupling is broken down by the act of light absorption.

The suggestion is rather vague. An alternative suggestion may be made. It is known from the works of Herzberg that in molecule formation, atoms are not always in their lowest state. Thus in SiN as well as in CN , the silicon and carbon atoms are in the $^1\text{D}_2$ -state, and not in the ^3P -states which are deeper. Probably in CrCl_3 , the d-shell of Cr^{+++} -ion is in the ^2Y -state, i.e., the spins of two electrons oppose each other. When light falls, the molecule breaks up, and the Cr^{+++} -ion takes up the more stable condition in which the electrons have their spins in the same direction.

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THE PHENOMENON OF HYSTERESIS IN THE SOL-GEL TRANSFORMATION OF AGAR SOLS

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I¹ have observed that the change in the viscosity of agar sol with age is very slow. I have concluded from these results that the aggregation tendency of agar particles and hence their orientation originating from a "loose crystallographic" force is a very slow process. In one of our publications on the phenomenon of hysteresis on the sol-gel transformation of reversible sols like those of gelatin and soap we have pointed out that a difference in the melting and setting points of such gels or sols exists due to a very slow process of orientation of the colloid particles. The slower the velocity of orientation, the greater is the hysteresis or the difference in the melting point of a gel and the setting point of a sol, in a definite time. I have, therefore, investigated the phenomenon of hysteresis in the sol-gel transformation of agar sols under various conditions. The details of these experiments were the same as followed in the case of gelatin and soap sols. The following were the experimental results with agar sols :—

Table 1

Concentration of the sol	Melting		Setting	
	Temperature °C	Time in minutes	Temperature °C	Time in minutes
1.5 per cent ...	75	1	27	11
	70	15	30	19
	65	3	35	>45
	60	15	...	...
	55	>30	...	....

Table 1—(contd.)

Concentration of the sol	Melting		Setting	
	Temperature °C	Time in minutes	Temperature °C	Time in minutes
2 per cent ...	80	1	27	8
	75	1.5	30	15
	70	2.5	35	>40
	65	21	...	...
	60	>30	...	...

2.5 per cent ..	80	1.5	27	4
	75	2	30	8
	70	3	35	32
	65	29	...	...
	60	>35	...	...

3 per cent ...	78	3.5	29	3
	75	6	32	5
	70	10	35	9
	65	34	38	16
	60	>40	40	>30

4 per cent ...	78	4.5	30	2
	75	8	32	3.5
	70	18	35	6.5
	65	>30	37	11
	...	...	40	28

Plotting my results on the melting and setting points of agar gels and sols, we find that the differences in melting and

setting points or the hysteresis in degree centigrades for 12 minutes of observation for different concentrations of agar sols are as follows:—

Table 2

Concentration of agar sol—% agar	1.5	2	2.5	3	4
Hysteresis in °C for 12 minutes	33.5	38	38	31.5	35

The hysteresis in sol-gel transformation of agar first decreases, passes through a minimum and then again increases with the increasing concentrations of agar. This result is similar to that obtained by me previously with soap and gelatin sols. An explanation based on the orientation of colloid particles and subsequent aggregation has been already developed by me in a previous paper. Moreover, it will be seen from my results that the hysteresis is remarkably high in the sol-gel transformation of agar sols. Thus with an agar sol of 4 per cent concentration, the difference between the melting and setting points for 12 minutes of observation is as high as 35°C, whilst I found that it is only 4.5°C with a 10 per cent gelatin sol when observations of the melting and setting points are taken for the same length of time. It will be interesting to note that the viscosity change of an agar sol with time is also very slow in comparison to that observed in the case of a gelatin sol. I, therefore, conclude that in the case of reversible sols like those of soap, gelatin, and agar, the slower the increase in the viscosity of these sols with age, the greater is the degree of hysteresis in the sol-gel transformation.

I have shown that in the sol-gel transformation the hysteresis is considerably lowered by sowing a sol with already formed gel, because this hastens the process of orientation. The following results on the hysteresis of agar sols by sowing with already formed gel and by stirring show that similar results are obtainable with agar sols:—

Table 3

[Concentration of agar sol=2 per cent.]

Complete melting		Setting					
		Ordinarily		Sown with already formed gel		Stirring	
Temp. °C	Time in mins.	Temp. °C	Time in mins.	Temp. °C	Time in mins.	Temp. °C	Time in mins.
80	1	27	8	27	5	27	6
75	1.5	30	15	30	11	30	13
70	2.5	35	>40	35	29	35	>30
65	21						
60	>35						

If we plot time-temperature curve, it is seen that the amount of hysteresis of 2 per cent sol for 12 minutes diminishes from 39° to 34° on sowing and 35° on stirring.

I am of opinion that the formation of a gel or separation of thick gelatinous precipitate in the cases of sol-gel transformation resembles to some extent the separation of solid phase from a supersaturated solution. When a sol is gradually cooled more and more of aggregated molecules and colloid micellæ appear and are in an oriented condition. The orientation is caused by a similar kind of force which causes crystallization, but the particles both of molecular and colloidal-dimension are unable to form coarse aggregation because they are protected by a layer of water present on the surface of these particles. My experimental results on the gelation of agar sols show that previous inoculation of sols with gels of the same concentration and temperature remarkably hastens the process of gelation and hence this has a close resemblance to the separation of a solid from a supersaturated solution by the introduction of a germ crystal.

Bradford² points out the formation of a gel by cooling a sol—a case of crystallization. Moeller¹ likewise believes gelatinisation to be a kind of crystallization in which there is formed a lattice of crystal threads that entrains a liquid, and von Weimarn concludes from his investigations that a jelly is a sponge composed of highly dispersed crystallized granules

soaked in dispersive medium from a supersaturated solution. It may be of interest to recall here that the process of sol-gel transformation is a continuous process and there is no evidence to show that aggregation of colloid particles or of heavy molecules present in a gelatin, soap or agar sol is suddenly rapid when a gel separates out. Thus Walpole* showed that the refractive index changes slowly but continuously as a gelatin sol is allowed to gelatinise. I have observed with 1 per cent agar sol when allowed to gelatinise slowly at the temperature of 29.5°C, the change in the extinction coefficient as observed with a Nutting Spectrophotometer in the region $\lambda=6000\text{\AA}$ is extremely slow and is practically constant. The extinction coefficient is given by $\Sigma=D/t$, where D is the reading on the density scale and equal to $2 \log_{10} \tan \theta$, θ being the angular reading and t the thickness in centimetres of the absorbing substance. The following are experimental results:—

Table 4

[Concentration of agar sol=1 per cent Temperature =29.5]

Condition	Time in mins.	Extinction coefficient
Sol	5	0.12
"	20	0.12
"	35	0.12
Gel	50	0.12

From my above experimental results I conclude that there is practically no change in the number or size or structure of colloid particles during the course of the setting of agar sol because the amount of light transmitted does not differ and hence the percentage of the scattering of light by colloid particles is the same either for a sol or a gel.

It is well known that there exists a considerable disagreement as to the structure and phase of a gel system. Katz⁵ discusses a gel as a homogeneous phase whilst several investigators consider a gel as made up of two phases. Ultramicros-

copic study beginning with the work of Zsigmondy⁶ has shown that many gels are apparently without structure and in some cases, a structure is seen where fibrils join and intersect as long straight threads. McBain and co-workers⁷ report such structure in the case of some soap gels, whilst Barrett⁸ has shown the existence of fibrils in the case of fibrinogen.

I have already pointed out that the process of the separation of gel from a sol is not a sudden process and gelation of sols like agar, gelatin or soap is certainly a continuous process. I have shown in a previous paper that there is an orientation of colloid particles in the sol state and the sols may show a distinct rigidity. This orientation of colloid particles, which gives a rigidity to the sols, rapidly increases with the lowering of temperature and with time.

I, therefore, suggest that, at the moment when a gel is formed from a sol, the orientation of colloidal micellæ has reached the highest value to attain the rigidity which characterises a solid body from the condition of a liquid. When, therefore, the 1 per cent sol of agar is kept at a temperature of 30°C the number of colloidal micellæ is not increasing with increasing time but are gradually arranging themselves to an oriented form. This orientation is a very slow process because of the slow diffusion of the dispersed particles. When finally orientation has reached sufficiently a high value, the sol appears as a gel, where the aggregation of the dispersed agar particles is not much different from what it is when agar is in the sol condition. The coarsening is stopped as we have already pointed by the high hydration of the colloidal micellæ. When, however, the gel is kept for a sufficiently long time, the colloid particles gradually lose the affinity for water, get dehydrated and aggregation occurs and finally the phenomenon of syneresis is observable. It is well known that substances remarkably lose their absorptive capacity with time. I am of opinion that in those cases where an evidence of the structure of a gel has been obtained from ultra-microscopic observations, the colloid particles have lost some of the protecting layer of water and their aggregation has set in.

It may be of interest that E. Schalek and Szegvary⁹ studied the effect of shaking on the concentrated and aged sols of ferric hydroxide. These sols set to a gel on addition of an electrolyte of suitable concentration, the gels on shaking become less viscous and mobile again, and the sols thus formed gelate again, the whole process being capable of indefinite repetition. The authors have measured the viscosity change during gelation and have followed the process of the changes by an ultra-microscope. They show that in the course of gelation, the particles do not meet each other and their results greatly support our view as developed by us for the process of gelation from a sol.

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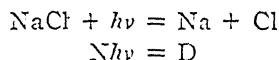
ON THE ABSORPTION SPECTRA OF SATURATED HALIDES OF MULTIVALENT ELEMENTS

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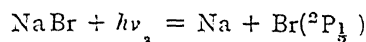
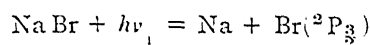
Received March 9, 1931.

The absorption spectra of alkali halides in the vapour state have received a good deal of attention in recent years from Angerer and Müller,¹ Müller,² Franck, Kuhn and Rolfeison.³ They found that the absorption spectra were strictly continuous, *i.e.*, started from a rather ill-defined long wavelength limit and stretched towards the ultraviolet. In the case of bromides and iodides, two absorption maxima were noted. In some cases there was re-transmission of the spectrum in the shorter wavelength side. Franck showed that the long wavelength limit of the continuous spectrum marks the photo-dissociation of the molecule into neutral atoms according to the scheme



D=heat of dissociation calculated from a Born cycle.

In the case of bromides and iodides the molecule, in addition may decompose into an excited halogen atom and a metallic atom, according to the scheme



This gives rise to a second absorption-beginning, removed to the short wavelength side by the difference $\Delta\nu = ^2P_{3/2} - ^2P_{1/2}$. This is present also in the case of chlorine, but as $\Delta\nu$ is small in this case, it cannot be distinguished from the first absorption-beginning. But in the case of NaBr and NaI, they obtain two absorption maxima, separated by the distance $\Delta\nu = ^2P_{3/2} - ^2P_{1/2}$, from which they conclude that the

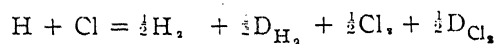
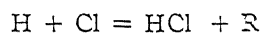
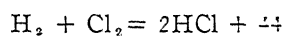
molecule NaBr decomposes into Na and $\text{Br}(^2\text{P}_{3/2})$ and Na and $\text{Br}(^2\text{P}_{1/2})$. (*Vide* Fig. 34, p. 230, Photo Processes by Griffiths and McKeown.)

The same consideration would hold also for hydrogen halides,⁴ but here the agreement is not good, as can be seen from the following table :—

Table 1

Substances.	Q (Heat of Formation).	R _{calc.} (Atomic Heat of Formation).	λ Observed long wavelength limit of absorption.	R _{obs}
HCl	22.0	105	2350	122
HBr	8.6	84	2640	108
HI	2.89	76	3320	86

The calculation of R in the third column is as follows :—



$$= \text{HCl} + 22 + 53.5 + 29$$

$$= \text{HCl} + 104.5$$

Hence R = 105 kcal.

$$[\text{D}_{\text{H}_2} = 107, \text{D}_{\text{Cl}_2} = 58]$$

The discrepancy between R calculated from photodissociation according to Franck's idea and R experimentally obtained is too large and is beyond experimental error. Hence Franck's rule does not seem to apply to the hydrogen halides. Franck is of opinion that the binding in HCl is non-ionic. A difficulty appears in the interpretation of the dipole moment of HCl molecule. The distance between the nuclei is found to be 1.28×10^{-8} cm. from an analysis of the rotation spectrum of HCl, but the

dipole moment is found to be 2×10^{-18} units. If we suppose that HCl consists of H^+ and Cl^- ions forming a closed shell, then μ , the dipole-moment, ought to be 3 times larger, being $1.28 \times 10^{-8} \times 4.70 \times 10^{-10} = 6 \times 10^{-18}$. Hence the presumption is that in HCl, the electron does not completely leave H and attach to Cl, giving rise to an ionic compound. But it is not completely atomic as in that case μ should be nil.

Another class of halides, like $AgCl$ and $ThCl$, give band absorption in addition to continuous absorption. These facts have not yet been satisfactorily explained.

No systematic investigation of the absorption spectra of the poly-atomic saturated halides has been undertaken so far, excepting some previous work of Evans⁷ and Leifson.⁴ The present work was taken up to see the implications of the above ideas in the case of the poly-atomic compounds. The halides so far investigated by us are CCl_4 , $SiCl_4$, $SnCl_4$, $TiCl_4$. These were chosen because they are usually volatile liquids and a large vapour pressure can be easily obtained.

For carrying out the experiment, an absorption tube of ordinary glass was used; to this was attached a bulb which contained the liquid under investigation. At first the quartz plates were fitted with sealing wax, but as it was attacked by chlorides, soluble silicate of soda was used to fix up the plates. For this the ends of the tube must be well ground. The spectrographs used were a Hilger E_3 and a bigger Leiss apparatus corresponding to E_2 of Hilger but with greater light gathering power. The source of continuous light was underwater spark of copper. Good continuous spectrum reaching up to λ 2000 was obtained after an exposure of 3 minutes in the E_3 and 5 to 7 minutes in the Leiss apparatus.

All the spectra showed continuous absorption and no trace of bands. In the case of $SnCl_4$ re-transmission was obtained for a short region after the first absorption beginning. The nature of re-transmission varies with vapour pressure and the points needs further careful investigation. The preliminary results are shown in the following table :—

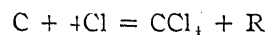
Table 2.—Results of experiment with tetra-halides

Substance.	λ Longwave limit.	Q_m in kcal	L_m of the element	$2.D_{Cl_2}$	Q heat of for- mation.	R	R/4
CCl_4	$240 \mu\mu$	118	282	58×2	68.5	466.5	117
$SiCl_4$	280 „	102	—	„	121.8	...	...
$TiCl_4$	328 „	87	—	„	—	.	...
$SnCl_4$	386 „	74	73.9	„	118	308	77

The second column gives the experimentally obtained values of λ and the third column gives the corresponding values of Q_m obtained from the quantum relation

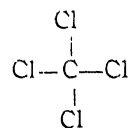
$$Q_m = Nh\nu_m / J$$

In column 7, we have given the value of R, the atomic heat of formation of the molecule. R may be defined by the reaction



where all the substances are supposed to be in the gaseous state and C and Cl are atomic. It is seen from comparison of columns 3 and 7 of the Table 2 that R is nearly $4Q_m$ in the cases where the data are available, and this is the main result obtained from the present investigation. The explanation seems to be quite simple.

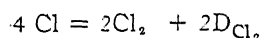
In a CCl_4 molecule, the structure may be imagined to be given by



If in continuation of Franck's argument we assume that the effect of light, producing continuous absorption in vapour, is to drive out one Cl atom from the molecule, then $h\nu_m = \frac{1}{4}R$ as the total R can be supposed to be equally distributed amongst all the 4 C-Cl bondages. The investigation seems to confirm this view.

R in the seventh column of the Table 2 has been calculated from the following reaction—

$$(C) = [C]_{\text{Dia}} + L_m$$



$$[C]_{\text{Dia}} + 2\text{Cl}_2 = \text{CCl}_4 + Q$$

Hence adding up we get,

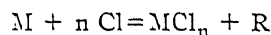
$$\begin{aligned} (C) + 4\text{Cl} &= \text{CCl}_4 + L_m + 2D_{\text{Cl}_2} + Q \\ &= \text{CCl}_4 + R \end{aligned}$$

L_m in the case of carbon has been taken from a calculation by Fajans from the vapour pressure of carbon as determined by Lummer. For the heat of dissociation of Cl_2 the latest accepted value by Franck has been taken. The value of Q has been taken from Landolt and Börnstein's tables [p. 1500, (1923)]. They are due to Thomsen.

For SiCl_4 , the value of L_m is still lacking. If the present ideas hold the value of L_m comes up as 178.2 kcal — a fairly probable value.

For SnCl_4 , the value of L_m is 73.9 kcal and is due to Greenwood and $Q=118$ kcal (L and B tables).

It cannot be said, however, on account of the uncertainty in some of the data* used, that the relation $R=4Q$ has been established. If it is true, we should expect that generally $R=nQ$ where we are treating a saturated poly-atomic halide with n chlorine atoms. R is the heat of reaction in the process.



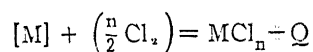
and is equal to $L_m + \frac{n}{2} D + Q - L_{\text{Com}}$, where L_m is the heat

* The uncertainty mostly refers to the latent heat of the element. Thus L_m for C is given for all values from 146 kcal to 280 kcal.

of evaporation from the solid state to the monatomic gas state.

D=heat of dissociation of Cl_2

Q=heat of reaction in the process



We can test the possibilities in some of the poly-atomic halides. The available data are given in the following table:—

Table 3

Element.	L_M Heat of Sublimation	$\frac{n}{2} D_{\text{Cl}_2}$	Q Heat of Formation.	L_{com} Heat of Sublimation of the chloride	R	$\lambda = \frac{R}{n}$
Be	...	57	112	...	...	...
Mg	47	"	151	...	$255 - L_{\text{com.}}$	...
Ca	44.2	"	190.3	...	$291.5 - L_{\text{com.}}$	...
Sr	...	"	195.6	...	...	...
Ba	...	"	197	...	...	...
Zn	31.3	"	97.2	...	$185.5 - L_{\text{com.}}$	...
Cd	27	"	93.2	10.5?	...	...
Hg	15.5	"	53.5	16.9?	...	...
B	...	84	(90)	...	...	...
Al	48	84	161	28?	...	...
In	...	"	128	...	...	...
Tl	38.2	"	80	...	$202.2 - L_{\text{com.}}$	...
Pb	46	114	...	...	...	...

In the case of di-valent halides the latent heat of the compound is not known excepting in the case of HgCl_2 for which it has been calculated from vapour pressure data. The absorption spectrum of HgCl_2 was studied by Evans' and has

again been studied recently in this laboratory by Deb and Mohanty. Without entering into details, it may be said that the results of the experiments do not agree with our theory. We should get continuous absorption at $\lambda=5280$, while Evans finds the beginning at $\lambda=3500$ while Deb and Mohanty find that the absorption begins at $\lambda=2500$. The data are therefore contradictory. But no trace of absorption has been found at the expected point. Fresh light has been thrown on the question of binding from the study of Raman effect of the chlorides. It has been found that the chlorides can be divided into two groups. Firstly, those which do not show Raman scattering and to this group belong most of the ionic compounds, NaCl for example.* Secondly, those which show Raman scattering. To this group belong most of the atom compounds including HgCl_2 . But it must be remembered that Raman effect has been studied only in the solid state and hence it may not be safe to deduce any conclusion from it regarding the nature of binding. Anyway, there may be expected some discrepancies in the case of some molecules, just as HCl does not fall in line with NaCl and other compounds. The subject is receiving further consideration.

References

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- ⁴ Leifson, *Astro. J.*, **63**, 73, 1926 and Tinge and Gerke, *Am. Chem. Soc. J.*, **48**, 1838, 1926.
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ON THE FIRST SPARK SPECTRUM OF TELLURIUM

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The spectra of heavy elements are interesting from a number of standpoints. For the light elements, the structure of the emission spectra can be fairly well accounted by the Pauli-Hund theory. In these cases the number of lines actually observed in the emission spectrum is exactly equal to the number of predicted lines arising from the different term-combinations. But in the case of heavy elements the system gets somewhat overburdened with the number of electrons, with a greatly increased number of its optical levels, with the heavy mass of its nucleus and with the disobedience of the series electrons to travel in its simple elliptical path at all. To get a real insight into all these various effects it is necessary to study the relation existing amongst the lines of the spectrum as in the case of the light elements. But before doing that it is also necessary to search out the lines which arise from similar electron configurations in the case of similar elements and ions, *e.g.*, Sb, As, Se⁺, S⁺, O⁺, etc. Our present work is an attempt to find out the lines due to the transitions allowed by the Hund-Pauli-Heisenberg rules for the first spark spectrum of tellurium.

So far as we are aware of no work has been done on the spectrum of Te in any of its ionised states, but two notes on this subject are worth mentioning :—

- (1) McLennan, McLay, and McLeod.¹ On the arc spectrum of Te in the ultra-violet and in the visible. But it is a very incomplete piece of work.

- In our analysis we were very much helped by the publication by L. and E. Bloch³ of their work on the spectra of Te due to different stages of ionisation.

We were guided in our investigation by the two important laws in the field, *viz.*, the 'Horizontal Comparison Law' and the 'Irregular Doublet Law'.⁸ We do not wish to describe them in detail here for nearly every paper from this laboratory contains more or less a good description of them, and it is therefore thought unnecessary to repeat them here. The Chart I, given on page 28, shows the principal lines of (6s-6p) transition of all the elements as the 5p-level is being filled up one by one.

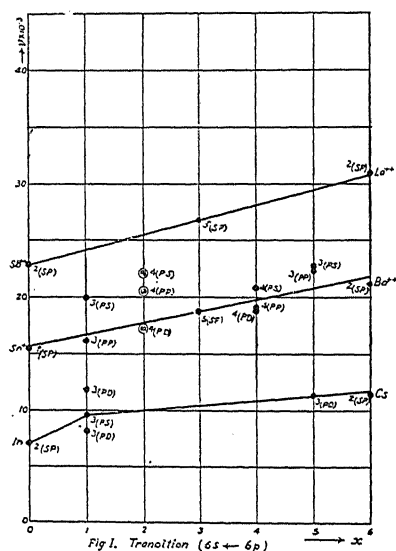


Fig 1. Transition ($6s \leftarrow 6p$)

* Dr. Rao has subsequently published a paper on the spectrum of TeIV and TeVI in the Proceedings of the Royal Society of London, A, Vol. 138, pp. 220—27 (1931).

5p² [6s-6p]

$\kappa \rightarrow$	0	1	2	3	4	5	6
1		$^3P_2 - ^3D_3$	$^3P_3 - ^3D_3$		$^4P_3 - ^3D_4$	$^3P_2 - ^3D_3$	
2	$^2S_1 - ^2P_2$	$^3P_2 - ^3P_2$	$^4P_3 - ^3P_3$	$^4S_2 - ^3P_3$	$^3P_3 - ^4P_3$	$^3P_2 - ^3P_2$	$^2S_1 - ^2P_2$
3		$^3P_2 - ^3S_1$	$^3P_3 - ^4S_2$		$^3P_3 - ^4S_2$	$^3P_2 - ^3S_1$	
I	In	Sn	Sb	Te	I	Xe	Cs
1		8376	—	—	—	11335	
2	7775	8605	—	—	—	22094	11732
3		9560	—	—	—	22211	
	Fowler's "Report" Calculated	Randall & Wright Phys. Rev. 38, 457. (1931)				B.S. Journ. Res. 3, 731 (1929)	Fowler's "Report" p. 107.
II	Sn+	Sb+	Te+	I+	Xe+	Cs+	Ba+
1		12863	17368		18723	—	
2	15492	16715	20544	18294	18890	—	21952
3		19992	21934		20636	—	
	Green & Loring Phys. Rev. 30, 5. (1929)	D. G. Dhavale Proc. Roy. Soc. 131, 109. (1931)	Deb and Mohanti (This paper)	Deb. (Unpub- lished)	B.S. Journ. Res. 6, 287. (1931)		Fowler's "Report" p. 137.
III	Sb++	Te++	I++	Xe++	Cs++	Ba++	La++
1		—	—		—	—	
2	21771	—	—	26437	—	—	31520
3		—	—		—	—	
	R.J. Lang, Phys. Rev. 35, 445. (1930)			Deb and Dutt. Zs. f. Phys. 62, 138 (1931)			Gibbs and White Proc. Nat. Acad. Sc. 12, 554 (1926)

CHART I

5p[∞] [6p←6d].

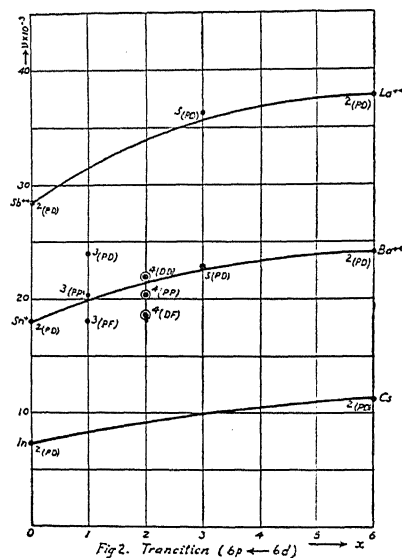
x→	0	1	2	3	4	5	6
1		$^3P_2 - ^3D_3$	$^4D_3 - ^4D_4$		$^4S_3 - ^4P_2$	$^3P_2 - ^3D_3$	
2	$^2P_2 - ^2D_3$	$^3P_2 - ^3P_2$	$^4P_3 - ^4P_3$	$^3P_3 - ^3D_4$	$^4D_4 - ^4F_5$	$^3D_3 - ^3F_4$	$^2P_2 - ^2D_2$
3		$^3P_2 - ^3F_4$	$^4D_3 - ^4F_5$		$^4P_3 - ^4D_4$	$^3S_1 - ^3P_2$	
I	In	Sn	Sb	Te	I	Xe	Cs
1		—	—	—	—	—	
2	6950	—	—	—	—	—	11410
3		—	—	—	—	—	Hicks' "Analysis of spectra", p. 252.
II	Sn ⁺	Sb ⁺	Te ⁺	I ⁺	Xe ⁺	Cs ⁺	Ba ⁺
1		20498	22036		—	—	
2	17969	17977	20544	22674	—	—	24202.2
3		24182	17158		—	—	
	Green and Loring, Phys. Rev. 30 5, (1921).	Dhavale Pro. Roy. Soc. 131, 109, (1931).	Deb and Mohanti. (This paper).	Deb (Unpublished)			Fowler's "Report," p. 137.
III	Sb ⁺⁺	Te ⁺⁺	I ⁺⁺	Xe ⁺⁺	Cs ⁺⁺	Ba ⁺⁺	La ⁺⁺
1		—	—		—	—	
2	28530	—	—	36788	—	—	37700
3		—	—		—	—	
	R. J. Lang Phys. Rev. 35, 445, (1930)			Deb and Dutt, Zs. f. Phys. 62, 138, (1931)			Badami, J. S. Proc. Phys. Soc., London. 43.53, (1931)

CHART II

A graph is plotted taking the frequency of the principal lines of each transition as ordinate and the number of electrons in the 5p-level as abscissa. It is shown above (Fig. 1).

It is evident from the graph that the region of (6s-6p) transition of Te^+ spectrum is about $\nu=17000$; the abundance of strong lines in that region is quite in agreement with our prediction.

A similar procedure for (6p-6d) transition was followed and a chart [Chart II, p. 29] similar to the Chart I was prepared.



A graph was also drawn in the similar manner taking the frequency of the line lying near the centre of gravity of the transition as ordinate and the number of electrons in the 5p-level as abscissa (Fig. 2). The table and the graph will show the position of the (6p-6d) transition for Te^+ . It is about $\nu 18000. \text{ cm}^{-1}$.

With these clues and with the help of the constant differences occurring between the lines in those regions we could classify about 90 lines of the first spark spectrum of Te as arising from the electron-transitions (6s-6p, 6p-6d) and (6p-7s). The classified lines are given in Table 1.

Table 1.—List of classified lines.

λ	Int	$\nu_{(\text{vac})}$	Combinations
2606.91	4	38348.1	$6p^4D_3-7s^4P_3$
2649.80	3	37727.4	$6p^4D_1-7s^4P_2$
2686.48	3	37212.4	$6p^4D_2-7s^4P_2$
2711.61	7	36867.6	$6p^4D_4-7s^4P_3$
2740.37	5	36480.6	$6p^4D_3-7s^4P_2$
2761.27	4	36204.5	$6p^4D_1-7s^4P_1$
2801.16	3	35689.0	$6p^4D_2-7s^4P_1$
2886.81	4	34360.2	$6p^4P_2-7s^4P_3$
2967.21	10	33691.8	$6p^4P_3-7s^4P_3$
2997.95	4	33346.4	$6p^4P_1-7s^4P_2$
3051.48	6	32761.5	$6p^4P_2-7s^4P_2$
3095.27	7	32298.0	$6p^4S_2-7s^4P_3$
3112.00	4	32124.4	$6p^4P_1-7s^4P_1$
3141.62	3	31821.5	$6p^4P_3-7s^4P_2$
3179.95	4	31438.0	$6p^4P_2-7s^4P_1$
3285.29	5	30430.0	$6p^4S_2-7s^4P_2$
3434.40	2	29108.8	$6p^4S_2-7s^4P_1$
3978.71	3	25126.1	$6p^4D_3-6d^4P_3$
4006.50	6	24952.4	$6p^4D_2-6d^4P_2$
4056.73	2	24643.3	$6p^4D_1-6d^4P_1$
4101.07	6	24376.9	$6s^4P_1-6p^4S_2$
4127.34	5	24221.9	$6p^4D_3-6d^4P_2$
4143.03	4	24131.3	$6p^4D_2-6d^4P_1$
4190.90	3	23854.4	$6p^4D_1-6d^4D_2$
4211.32	2	23738.8	$6p^4D_2-6d^4D_3$
4219.76	4	23691.4	$6p^4D_1-6d^4D_1$
4246.47	6	23542.3	$6p^4D_4-6d^4P_3$
4250.41	4	23520.5	$6p^4D_3-6d^4D_4$
4261.08	8	23461.6	$6s^4P_2-6p^4S_2$
4283.06	3	23341.4	$6p^4D_2-6d^4D_2$
4345.41	4	23006.4	$6p^4D_3-6d^4D_3$
4421.14	4	22612.3	$6p^4D_3-6d^4D_2$
4529.54	4	22071.1	$6s^4P_2-6p^4P_3$
4535.83	3	22040.5	$6s^4P_1-6p^4P_2$
4536.67	7	22036.3	$6p^4D_4-6d^4D_4$
4557.84	9	21934.1	$6s^4P_3-6p^4S_2$
4645.22	4	41521.5	$6p^4D_4-6d^4D_3$
4670.11	3	21406.8	$6p^4P_2-6d^4P_3$
4681.06	5	21356.7	$6s^4P_1-6p^4P_1$
4719.12	2	21184.4	$6p^4P_1-6d^4P_2$
4731.27	7	21129.9	$6s^4P_2-6p^4P_2$
4866.22	10	20544.1	$6s^4P_3-6p^4P_3$
4876.78	8	20499.5	$6p^4P_2-6d^4P_2$
4885.22	8	20464.2	$6p^4P_3-6d^4P_3$
4890.23	3	20443.2	$6s^4P_2-6p^4P_1$
4908.65	4	20366.5	$6p^4P_1-6d^4P_1$

Table 1.—List of classified lines.—(contd.)

λ	Int	ν (vac)	Combinations
5020.44	2	19912.9	$6p^4D_1-6d^4F_2$
5079.47	3	19681.6	$6p^4P_2-6d^4P_1$
5105.55	3	19581.1	$6p^4D_2-6d^4F_3$
5107.22	3	19574.7	$6p^4P_1-6d^4D_2$
5112.02	3	19556.2	$6p^4P_3-6d^4P_2$
5149.90	2	19412.5	$6p^4P_1-6d^4D_1$
5180.86	1	19396.4	$6p^4D_2-6d^4F_2$
5183.71	4	19285.9	$6p^4P_2-6d^4D_3$
5238.07	4	19085.7	$6p^4D_3-6d^4F_4$
5240.69	4	19076.2	$6p^4S_2-6d^4P_3$
5292.27	3	18889.7	$6p^4P_2-6d^4D_2$
5300.67	6	18860.3	$6p^4P_3-6d^4D_4$
5303.72	3	18849.4	$6p^4D_3-6d^4F_3$
5338.51	2	18727.6	$6p^4P_2-6d^4D_1$
5449.82	7	18344.2	$6p^4P_3-6d^4D_3$
5569.38	3	17950.3	$6p^4P_3-6d^4D_2$
5618.47	4	17793.5	$6s^4P_1-6p^4D_2$
5679.71	4	17601.6	$6p^4D_4-6d^4F_4$
5741.66	8	17411.7	$6s^4P_2-6p^4D_3$
5756.85	4	17365.7	$6p^4D_4-6d^4F_3$
5755.87	10	17368.8	$6s^4P_3-6p^4D_4$
5762.60	3	17348.5	$6p^4S_2-6d^4P_1$
6785.23	3	17280.6	$6s^4P_1-6p^4D_1$
5826.45	7	17158.4	$6p^4D_4-6d^4F_5$
5898.26	4	16940.4	$6p^4S_2-6d^4D_3$
5993.94	6	16679.0	$6s^4P_2-6p^4D_2$
5939.00	2	16554.5	$6p^4S_2-6d^4D_2$
6184.39	4	16165.3	$6s^4P_2-6p^4D_1$
6293.61	6	15884.7	$6s^4P_3-6p^4D_3$
6392.65	3	15638.6	$6p^4P_1-6d^4F_2$
6596.32	3	15155.8	$6s^4P_3-6p^4D_2$
6605.88	3	15133.9	$6p^4P_2-6d^4F_3$
6686.86	3	14950.5	$6p^4P_2-6d^4F_2$
6930.51	5	14425.0	$6p^4P_3-6d^4F_4$
7135.34	3	14010.9	$6p^4P_3-6d^4F_2$

In conclusion we express our heartfelt thanks to Prof. M. N. Saha, D.Sc., F.R.S., for his interest in the work.

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RELATION BETWEEN LIGHT INTENSITY AND THE VELOCITY OF PHOTOCHEMICAL REACTIONS

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In publications¹ from these laboratories, we have investigated the influence of the variation of intensity of the incident radiation on the velocity of several photochemical reactions.

The source of light in most reactions was a 1,000 watt gas filled tungsten filament lamp operated at 4.6 amperes. In some reactions sunlight was also utilised. In order to obtain monochromatic light both solution and glass filters were used.

By changing the diameter of the aperture of an iris diaphragm, the amount of light falling on the reaction vessel and hence the intensity was varied. The intensity of light was taken to be directly proportional to the area of the aperture through which the light passed before falling on the reaction vessel.

In order to make sure that the absorption of radiation is proportional to the intensity of the incident radiation, we have determined the absorption of the incident radiation by either a radiomicrometer or a Moll thermopile and a sensitive galvanometer. We have observed that the amount of radiation absorbed is directly proportional to the intensity of the incident radiation.

In all the reactions, the velocities in the dark were deducted from the total changes observed in light in order to get the velocity in light alone.

From our investigations with twelve reactions, we have advanced the view that the two important factors, which are

of consequence in the relation between intensity and the velocity of a photochemical reaction are:—

- (i) The acceleration of the reaction in presence of light.
- (ii) The amount of absorption of the incident radiation by the reaction system.

When the absorption of radiation is high and the reaction is not markedly photochemical in nature and the velocity of the reaction in the dark is appreciable direct proportionality or even square of intensity is likely to be observed. On the other hand, when the reaction is highly photochemical in nature and the velocity of the dark reaction is practically negligible, square-root relationship will be expected.

We have been successful in changing the relationship between the intensity and velocity of the reactions between Potassium oxalate and Iodine; Rochelle salt and Bromine; Quinine sulphate and Chromic acid; Sodium formate and Iodine; Potassium oxalate and Bromine; Oxalic acid and Chlorine; Inversion of cane sugar; Sodium nitrite and Iodine; Ferrous sulphate and Iodine; Citric acid and Chromic acid; Hydroxylamine hydrochloride and Iodine; Hydrazine hydrochloride and Iodine from almost 2 to $\frac{1}{2}$. By increasing the velocity of the dark reaction and exposing the reaction mixture to radiation which is slightly absorbed by the reacting system, a truly photochemical reaction, which is proportional to the square root of the incident radiation or the amount of energy absorbed becomes directly proportional to the intensity of the incident radiation or the amount of energy absorbed. On the other hand, a photochemical reaction which is proportional to the square of the incident radiation or is directly proportional can be made to be proportional to the square root of the incident radiation by decreasing the dark reaction velocity and increasing the photochemical velocity.

Our conclusions throw a flood of light on the highly controversial question of the relation between intensity and velocity in the reaction between chlorine and hydrogen. Draper,² Mrs. Chapman,³ Kornfeld and Müller,⁴ Allmand and

workers^a observed that the photochemical reaction between chlorine and hydrogen is directly proportional to the intensity of the incident radiation whilst Baly and Barker^b showed that the velocity increased more rapidly than the intensity. All these workers have used total light from electric bulbs.

Recently Marshall^c has investigated the same problem in presence of mercury arc light. His results show that the combination of chlorine and hydrogen in presence of mercury lamp radiation which is more intense than the light used by previous workers, is proportional to less than the square root of the incident radiation.

On considering the details of the experiments of Mrs. Chapman, and those of Baly and Barker, we are of the opinion that there was more oxygen present in Baly and Barker's experiments than in Mrs. Chapman's gas and this will be evident from the following lines from Baly and Barker's paper: "During the course of this work we encountered considerable difficulty owing to the production of oxygen in the reaction vessel."

Moreover, the light intensity in the experiments of Mrs. Chapman was greater than in the case of Baly and Barker. It is well known that oxygen markedly retards the photochemical combination of hydrogen and chlorine, hence it appears that the photochemical reaction velocity in the experiments of Baly and Barker was not as much accelerated as that of Mrs. Chapman, consequently Baly and Barker observed a tenfold increase in velocity by increasing the light intensity sixfold, whilst Mrs. Chapman working with a purer reacting system, containing less oxygen and under more intense light than that used by Baly and Barker observed about 5.5-fold increase of velocity on sixfold increase of light intensity.

Marshall working with very pure reacting substances and with intense light from a mercury arc obtained a relation, which is less than square root for the same chemical change. Hence the photochemical combination of chlorine and hydrogen can show less than square root direct or nearly square relationship depending on the acceleration caused by light.

Bodenstein and Lutkemeyer⁸ have announced that the union of hydrogen and bromine in light is proportional to the square root of the energy absorbed when the intensity of light is kept constant. It will be interesting to observe that the velocity of the same reaction taking place in the light is 30 times greater than that taking place in the dark. Consequently the combination of bromine and hydrogen is highly photochemical in nature. Briers and Chapman⁹ have recently found that the rate of interaction of hydrogen and bromine for very high intensity of light approximates to values which are square root to the values of the intensity but for low intensities the rate becomes more nearly equal to values proportional to intensity.

Those reactions where square root relationship is observed are largely accelerated by light and their thermal reactions are extremely slow in comparison with the reaction in light alone. In these reactions many molecules are readily activated by the absorption or radiation on illumination and consequently further increase in light intensity is not likely to increase the velocity of reaction markedly.

A fast dark reaction when illuminated has much less chance of showing direct proportionality relationship than a slow reaction, because in a fast reaction many more molecules are in the active state and there is less chance of further activation of molecules on increased illumination than in the case of slow reactions. As a matter of fact our experimental results show that the reaction between potassium permanganate and lactic acid or tartaric or citric acid in presence of strong light increases much less rapidly than intensity and these reactions have been proved to be fast in the dark.

Our researches further prove that both the views regarding the chemical change effected by light are not correct. Following the lead of Draper a class of photochemists think that the amount of changes in a given system is directly proportional to the light absorbed but our results show that the amount of chemical change of a truly photochemical system where the reaction is largely accelerated by light, is proportional

to the square root or even less than square root of the light absorbed.

The second view put forth by Berthoud¹⁰ emphasises that the primary process in the photochemical reactions with halogens as one of the reacting substances is the dissociation of halogen molecules into atoms as the result of their absorption of light, the halogen atoms then reacting at a rate proportional to the first power of their concentration. But in foregoing papers¹¹ we have shown that this point of view of Berthoud need not always be correct. We have observed that the reaction between potassium oxalate and iodine is proportional to the square root of the incident radiation from a 1,000 watt gas filled tungsten filament lamp; whilst the reaction between sodium lactate and iodine is directly proportional to the intensity; hence the conception that the halogen molecules are atomised on illumination does not help us in understanding the mechanism of those reactions with halogens as one of the reacting substances and where the velocity of reaction is directly proportional or proportional to the square of the intensity of the incident radiation. Our experimental results show that the reaction between sodium lactate and iodine is only slightly accelerated by light and consequently the inactive molecules available for activation on illumination is large and hence direct proportionality is observed. Moreover, we have shown in the case of several photochemical reactions that the relation between velocity and intensity of one and the same reaction is not a fixed quantity but can vary from a proper fraction to 2 or more depending on the acceleration of the photochemical reaction over the thermal reaction.

We are, therefore, of the opinion that this explanation of the difference of intensity effect on different photochemical reactions is more satisfactory than any other view.

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SENSITIZATION OF STANNIC HYDROXIDE SOL BY SILICIC ACID SOL

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It is well known that if sols containing colloidal particles of opposite charge are added in the requisite proportion coagulation sets in. Few cases are, however, also known where coagulation is observed when colloidal solutions of the same charge are mixed together. Thus Freundlich and Nathanson¹ reported that a negative As_2S_3 sol is rendered turbid and flocculated by Odén sulphur sol. This joint flocculation of similarly charged particles is well known in analytical chemistry, that metallic hydroxides have a strong tendency to separate out together and that one hydroxide carries another down with it under conditions in which it would otherwise remain in solution.

A few years ago, we² showed that the protective colloids like gelatine, albumin, etc., which are negatively charged possess a different effect when added in small quantities to some negatively charged colloids. Instead of stabilizing the colloids traces of gelatine, albumin, etc., were found to make the colloids more sensitive to the action of electrolytes. We have proved that this sensitization is certainly not due to the polar nature of the protective colloid as has been suggested by different investigators³ in this line, but is due to the H ion concentration of the medium.

This investigation was carried on to show if our view is correct with inorganic colloids as well. Stannic hydroxide and silicic acid were chosen for the experiments as we found that these sols are remarkably sensitive to the variation of

hydrogen ion concentrations of the medium in which the colloid particles are dispersed. Silicic acid sol was prepared by hydrolysing silicon tetrachloride and stannic hydroxide sol was prepared according to the method of Zsigmondy.*

Coagulation experiments were carried on with these sols separately and with their mixtures by various electrolytes. Stannic hydroxide sol as prepared by us is sensitive to the action of electrolytes and monovalent cations of normal concentration can coagulate the sol, whilst silicic acid is very insensitive to the action of electrolytes. Silicic acid sol could not be coagulated by either a monovalent or a polyvalent cation.

When a measured volume of silicic acid was added to a definite volume of stannic hydroxide, the mixture of the two sols becomes very sensitive to the electrolytes. The amounts of KCl , BaCl_2 and $\text{Al}(\text{NO}_3)_3$ necessary for coagulation of pure stannic hydroxide sol were considerably diminished by the addition of silicic acid. When the amounts of silicic acid sol added are gradually increased, the sol of stannic hydroxide becomes more and more sensitive towards the electrolytes and finally passes through a minimum. When more of silicic acid sol is added it possesses a stabilising influence on stannic hydroxide sol.

It was thought desirable to see if the coagulated mass contained only stannic hydroxide or if it carried with it any silicic acid. On analysis it was found that during the course of the coagulation of stannic hydroxide sol, silicic acid is also taken down with the precipitate so much so that no silicic acid is left behind in the colloidal state. This result seems to be important in view of the fact that silicic acid sol is highly stable and cannot be coagulated by electrolytes.

In order to clarify the mechanism of the sensitising influence of one negatively charged sol over the other, the measurement of hydrogen ion concentrations was necessary and accordingly we measured the H^+ ion concentration by using indicator method of Michaelis for finding P_H -values. Nitrophenols were used as indicators.

The measurement of P_H -values of the sols separately and their mixtures showed that H^+ ions play an important rôle

in the sensitization of stannic hydroxide sol by silicic acid. Stannic hydroxide sol, which is prepared by peptising stannic hydroxide by traces of ammonia and then subsequent dialysis was found to be distinctly alkaline (P_H -value 4.95), whilst silicic acid showed an acid reaction (P_H -value 8.8). It was found that the maximum sensitization of stannic hydroxide sol was in the neighbourhood of P_H -value 7.10 of the mixture of the sols.

These results on the measurement of P_H -values greatly confirm our view that H^+ ions are important in the mechanism of sensitization. It is well known that the stabilising ion of stannic hydroxide sol is OH^- ion from ammonia. Destruction of OH^- ions by H^+ ions present in excess in silicic acid is the cause of sensitization of stannic hydroxide sol by the introduction of silicic acid. In one of the publications we showed that silicic acid owes its stability in the colloidal conditions due to slight acidity from small quantities of silicic acid present in the sol in the true molecular form. Accordingly OH^- ions, on the other hand, have a sensitizing influence on silicic acid. This has been proved by us in detail elsewhere.⁵

It may be of interest to note here that we carried on further investigations on the coagulation of silicic acid sol in presence of NH_4OH by different electrolytes and it was found that the slight difference in the P_H -value that is caused by the OH^- ions present in stannic hydroxide sol cannot explain the complete coagulation of silicic acid from a mixture of stannic hydroxide and silicic acid sols. Thus silicic acid of P_H -value 6.3 required 2N KCl for complete coagulation, whilst N/10 KCl was sufficient to coagulate silicic acid from a mixture of stannic hydroxide and silicic acid sols of the same P_H -value. We are of opinion that silicic acid sol is more easily coagulated in the presence of stannic hydroxide because of adsorption of silicic acid by stannic hydroxide.

It is, therefore, apparent that the sensitization of one sol by another sol of the same charge is due to (a) removal of the stabilizing ions by mutual reaction, and (b) adsorption of a colloid by the precipitating mass.

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A THEOREM ON INTEGRAL FUNCTIONS

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(ABSTRACT)

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The main result of the paper is the following theorem:—

Theorem.—If

(1) $\phi(z)$ be an integral function of z of order of magnitude $e^{\epsilon(r)}r$, where $|z|=r$, and ϵ is positive and tends to zero as r tends to infinity;

(2) $\int_0^\infty \phi(\pm t) dt$ is absolutely convergent;

then $\phi(z)$ is identically zero.

The proof of the theorem is extremely simple and rests on an application of the well-known Laplace-Abel integral.

Let $\phi(z) = \sum_{n=0}^{\infty} \frac{a_n z^n}{n!}$. Then the integral function

$f(x) = \sum_{n=0}^{\infty} a_n x^{n+1}$ is defined by the integral $\int_0^\infty e^{-\frac{t}{x}} \phi(t) dt$

in the region $|x| \geq 1$ and $|\operatorname{amp} x| \leq \frac{\pi}{2}$, and by the integral

$-\int_0^\infty e^{\frac{t}{x}} \phi(-t) dt$ in the region $|x| \geq 1$ and $|\operatorname{amp} x| \geq \frac{\pi}{2}$, so

that, by virtue of (2), $|f(x)| < K$, a constant, throughout the whole plane. Hence all the a 's are zero and consequently $\phi(z)$ is identically zero.

This theorem enables me to prove the following theorem of Phragmén and Lindelöf in a manner that leaves hardly anything to be desired in the matter of simplicity.

Theorem.—If $\phi(z)$ satisfies the condition (I) and tends to zero as $|z|$ tends to infinity along the real axis, then $\phi(z)$ is identically zero.

For another proof of this theorem see Wigert's paper 'Une théorème sur les fonctions entières' in *Arkiv för Matematik Astronomi och Fysik*, Bd. 15, No. 12, 1921.

An immediate consequence of Phragmén-Lindelöf's theorem is this: An integral function of order $e^{\epsilon(r)\sqrt{r}}$ which vanishes when z tends to infinity along the positive real axis is identically zero.

That this result ceases to be true when $\phi(z)$ is an integral function of order $e^{k\sqrt{r}}$, where k is some positive number, is seen by considering the function $\frac{\sin \sqrt{z}}{\sqrt{z}}$. But what is true of this class of functions in this direction is given by the following theorem:—

If $\phi(z)$ be an integral function of order $e^{k\sqrt{r}}$, where $k > 0$, and tends to zero as $z \rightarrow \infty$ along the positive real axis, then on no other radius vector $\phi(z)$ can satisfy the relation $\phi(z) = O(e^{\epsilon\sqrt{r}})$ for every positive ϵ , however small, unless $\phi(z)$ is identically zero.

Reference

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PHOTOCHEMICAL HYDROLYSIS OF CANE SUGAR

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Communicated by Prof. N. R. Dhar.

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In 1920 Lindemann¹ pointed out that on the basis of the simple radiation hypothesis, the inversion of cane sugar solution must be enormously accelerated in presence of sunlight, but he stated that the reaction actually proceeds at the same velocity whether it is exposed to sunlight or not.

In publications² from these laboratories, it has been shown that the statement of Lindemann is not correct and that a solution of cane sugar in tropical sunlight is completely inverted even in absence of acids on long exposure, whilst in presence of hydrochloric acid, sugar inversion is distinctly accelerated by sunlight. Banerji and Dhar³ investigated the kinetics and temperature coefficients, quantum yield and the relation between the light intensity and the velocity of cane-sugar hydrolysis in radiations of different wavelengths. In isolating different spectral regions, Bhattacharya and Dhar used a 1000 watt tungsten filament lamp and glass filters.

In this paper we have investigated the velocity of sugar hydrolysis in presence of radiations of different wavelengths obtained by using some solution light filters. We have also studied the relation between the light intensity and the velocity of the reaction in different radiations. The quantum yield was determined by a Moll thermopile and a sensitive galvanometer.

It was clear from our results that in all the cases the temperature coefficients of the photochemical changes are less than those of the corresponding thermal reactions. The greater the acceleration in light of different wavelengths, the less the temperature coefficient.

The velocity of hydrolysis increases as the wavelength decreases. Einstein's law of photochemical equivalence is not at all applicable in the photochemical hydrolysis of cane sugar. Many molecules of sucrose are hydrolysed per quantum of light absorbed. The quantum yield increases with the temperature and the acceleration of the light reaction over the dark reaction.

The concentration of hydrochloric acid has considerable influence on the velocity of the light reaction. Our results show that the ratio of true light reaction and dark reaction decreases as the concentration of hydrochloric acid increases. This is due to the fact that the dark reaction is much increased by increasing the concentration of hydrochloric acid.

Our experimental results prove that the inversion of sucrose can be accelerated by radiation of wavelength 8500 Å which lies in the infra red region. The wavelength calculated according to the radiation hypothesis has the value 11900 Å. We are of the opinion that this wavelength obtained from the temperature coefficient of the dark reaction is the threshold limit. No acceleration of sucrose inversion is possible with radiations of wavelengths longer than 11900 Å. Radiations of wavelengths shorter than 11900 Å are capable of accelerating the velocity of sugar inversion.

Our experiments on the relation between intensity and velocity of the hydrolysis of cane sugar show that the relation between the two varies from less than 1 to $3/2$ depending upon the ratio of the thermal and photochemical reactions. These results show that by increasing the velocity of the dark reaction and exposing it to radiation, which is slightly absorbed by the reacting system, a photochemical reaction, which is proportional to the square root of the incident radiation becomes directly proportional to the intensity of the incident radiation.

From the measurements of the absorption of the incident radiation by a radiomicrometer, we find that the light absorption, is directly proportional to the intensity of the incident radiation. We venture to suggest that the velocity of sucrose

inversion is likely to be proportional to $1\frac{1}{2}$ and $1\frac{1}{3}$ when illuminated with intense ultraviolet radiations and that the relation between intensity or the absorption of the incident radiation and the velocity of a photochemical reaction can vary from any proper fraction to 2 depending upon the ratio of the thermal and photochemical velocities.

The results here obtained are in agreement with those obtained by Bhattacharya and Dhar using different glass and gelatine filters for the isolation of radiations of different wavelengths.

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MODIFICATION OF X-RAYS BY PASSAGE THROUGH MATTER

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In earlier communications to *Nature*¹ and in a recent communication to *Zeit. f. Physik*,² Dr. B. B. Ray of Calcutta described experiments which were undertaken to discover the Raman effect analogue in X-ray spectra. In these experiments which CuK_β , NiK_α , FeK_β radiations were passed through air and soot and the emergent beam was analysed by an X-ray spectrometer. He found on the photographic plate in addition to original radiation, new lines which corresponded to $\text{CuK}_\beta - \text{C}_K$, $\text{CuK}_\beta - \text{O}_K$, etc., and which were attributed by him to scattering by bound electrons; though he mentioned that these lines could not be detected in any direction other than that of the original direction of propagation of the primary radiations.

We looked upon the phenomenon as a case of modification through part absorption of the incident quantum resulting in photo-ionisation of an electron in the K-shell of the atom traversed. As such, there should appear a band rather than a line, with a sharp limit on the short wavelength side and extending on the long wavelength indefinitely. Support to our view is lent by experiments of Robinson³ on photoelectrons liberated by silver radiations from different substances in which these electrons always produced bands on photographic plate and experiments of Ellis⁴ and others on the measurement of wavelength of γ -rays.

In case of experiments by the latter, X-rays are assumed to have delivered the whole quantum of their energy according to the equation $h\nu = h\nu_0 + \frac{1}{2}mv^2$. Determination of v , the velocity of liberated electron and knowledge of r_K give the wavelength

of γ -rays. This is one limiting case and the other limiting case will be the one in which the incident radiation of frequency ν will part with just as much energy as is sufficient for the removal of an electron from the K, L or M shell and move forward with the balance of energy according to the equation $h\nu - h\nu_{K, L, M}$. The incident quantum having the energy $h\nu$ may part with any energy greater than $h\nu_{K, L, M}$, the excess will appear as the kinetic energy of the liberated electron. In the experiments of Robinson, the incident radiation is delivering varying amounts of energy to the electrons which are liberated with varying velocities and thus give rise to bands when photographed. If the emergent beam be analysed by a crystal and the resulting spectrum photographed there should appear on the photographic plate a band with a sharp edge on the short wavelength side at $\nu - \nu_K$ or $\nu - \nu_L$. The alternative explanation of this band, that it is due to photo-electrons losing parts of their energy by passage through matter, does not appear convincing.

We undertook to verify the view put forward here and communicated to *Nature* [127, 273 and 305, (1931)].

The X-ray tube used in the experiments was of the Hadding⁵ type obtained sometime ago from the Kaiser Wilhelm Institute, Berlin-Dahlem through the good offices of Dr. Mark to whom our thanks are due. The cathode and the anti-cathode are water-cooled and it requires continuous pumping. As usual in gas tubes, the current and voltage can be adjusted by regulation of pressure inside the tube. It is connected to a four-stage diffusion pump across which a needle valve regulator is connected as a shunt. Its low vacuum side is connected to a Gaede oil pump through a large bottle, the advantage being that the oil pump need not be run continuously. In fact the oil pump is worked for a few minutes in the beginning and the pressure inside the tube adjusted by a vacuum regulator until it carries the desired current at a suitable voltage, it is then left to itself when it runs for at least 6 hours without any further attention and after this period the oil pump need be run for a few minutes again and the tube runs smoothly and steadily for another

period of 6 hours. Thus the same conditions can be easily maintained and reproduced.

A 16"-induction coil rated to deliver 2.5 kilowatts at 220 volts was used to run the tube from a 110-volt circuit through a mercury interrupter. The transformation ratio in the case of this coil was found from the tables to be 1000. The spectrometer used was of the Uhler-Cooksey⁶ type supplied by Messrs. Adam Hilger. It carries two lead slits opening both ways and separated by a distance which can be varied up to 20 cms. Its crystal holder has a motion about the horizontal axis and can be rotated through any angle about the vertical axis by an electromagnetic arrangement. We kept, however, the crystal fixed during the period of exposure. Its plate holder can be moved along an accurately graduated scale up to a distance of 36 cms. We kept the plate holder at a distance of 20 cms. from the crystal. The plate and crystalholder and slits are mounted on a massive base, so that if the adjustments are once made, there is no chance of their being disturbed during the period of exposure which was generally very long in these experiments. The plates used were Ilford Empress plates as recommended by Hilger.

The absorbing substance was put either on the window or on the second slit close to the crystal, which was calcite 25 mm. long \times 12 mm. broad having the reflecting surface well polished.

The width of the first slit was 2 mm. and that of the second 2 mms. Thus a divergent beam was used and in one setting of the crystal, wavelengths differing by 70X units were photographed.

When we used the radiation from a copper target, we took the photograph of first order K_{α} and first order K_{β} on the same plate, in order to get fiducial points. In another experiment, we used silver radiations as our primary ray, and, in order to get fiducial points we photographed, K_{α} and K_{β} in the first order and K_{α} in the second order.

In the first experiment CuK radiations passing through paraffin about one mm. thick, put on the window of the X-Ray

tube, were photographed; but the expected band due to the modification by carbon did not appear but a broad line, very close to the primary line, appeared on the long wavelength side. It was ascribed to photo-ionisation of hydrogen contained in the paraffin. The same experiment was repeated by substituting for the paraffin, 6 sheets of ordinary black paper used for wrapping photographic plates, and having a total thickness 1 mm.; the expected modification of copper K by carbon was recorded on the plate.

[As the validity of Dr. Ray's experiments has been questioned by some European and American workers,⁷ we give the details of our experiments as well as of the calculation. Unfortunately the lines are so faint on the plate that our attempts at reproduction failed.]

Experiment No. 1.

MODIFICATION OF CuK_β BY CARBON

Tube Voltage 30 K. V. ... Current ... 3 m. A
Exposure ... 5+ hrs. ... Primary Radiation $\text{CuK}_{\alpha, \beta}$

The distance between the K_{α_1} (fiducial line) and K_β was measured on a Hilger Comparator and found to be 13.186 mms. The distance $\text{K}_{\text{mod}} - \text{K}_\beta$ was found to be 3.988 mms.

From Siegbahn's⁸ tables the glancing angles for CuK_α and CuK_β were found to be $14^\circ 41' 50''$ and $13^\circ 15' 10''$ respectively. From this, by proceeding in the usual way, we found θ (the glancing angle) for modified line to be $13^\circ 41' 5''$ the wavelength corresponding to this angle was $1.4314 \text{X} \text{U}$.

We have $\frac{\nu}{R}$ for the modified line = 636.6

From Södermann's⁹ recent work we found

$$\frac{\nu}{R} \text{ for } \text{C}_K \dots 20.1$$

$$\text{and } \frac{\nu}{R} \text{ for } \text{CuK}_\beta = 655.9,$$

Hence $\text{CuK}_\beta - \text{Ck}$

$$= 655.9 - 20.1$$

$$= 635.8$$

The experimentally obtained value is therefore in good agreement with the value expected on theoretical grounds.

Experiment No. 2.

MODIFICATION OF Ag K_α BY NICKEL

CuK radiations were replaced by AgK radiations when modification by the heavier element Ni was sought.

The Ni piece put on the second slit was about 0.4 mm. thick and was supplied by Hilger for cutting off CuK_β radiations from Debye-Scherrer photographs.

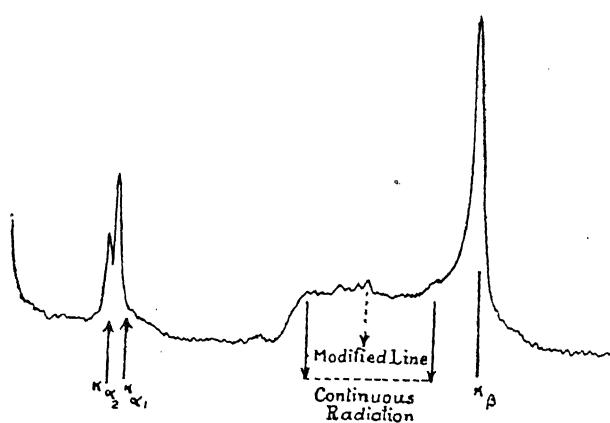
The plate was developed after an exposure of 300 m. A. hours, and it clearly showed the band due to modification of AgK_α by Nickel, with a sharp edge to the short wavelength side. On this plate besides the fiducial lines mentioned above, $\text{K}_{\alpha_1, \alpha_2}$ lines due to reflection from planes 102, 121, planes appear above and below the spectrum; and this proved useful in checking the results. The accuracy claimed is one in thousand.

Tube voltage ...	30 K. V.	Current	3m. A.
Exposure ...	100 hours.		

Proceeding as before the glancing angle for the edge of the band $= 8^\circ 29'$.

The wavelength corresponding to this angle $= 893.7 \text{X}^\circ \text{U}$.

From tables given by Siegbahn we find $\frac{\nu}{R}$ for $\text{Ag K}_\alpha = 1632.6$ and $\frac{\nu}{R}$ for the K-absorption limit of Nickel $= 612.0$ wavelength difference between these comes out to be 892.8 which is in fair agreement with the value 893.7 obtained above. As a check upon observations the value of wavelength of K_α of Nickel was



Micro-Photometric record of Copper Spectrum
Modified by Carbon

calculated from observations and found to be $563.21\text{X}^\circ\text{U}$. The value given by Siegbahn⁷ is $562.6\text{X}^\circ\text{U}$.

The agreement is therefore quite satisfactory. The modified line was in the nature of a band, and the above measurements refer to its short wavelength limit. The band is superposed by a continuous spectrum on both sides and though we are convinced of the existence of the band, we feel that unless the continuous spectrum is suppressed, the intensity distribution in the band cannot be followed. We expect to take up the question on a future date. We are also trying to push the accuracy still further.

Note added during proof correction

Several observers who could not reproduce this effect have suggested that these modified lines are due to some imperfection in the crystals used. Mr. Swarup Narayan Mathur of this laboratory has repeated these experiments with a new crystal of Gypsum and found the modified line at the expected place. We wish further to point out that the technique is extremely difficult and proper adjustment of the thickness of the absorbing material is very necessary before any result can be obtained.

Our best thanks are due to Prof. M. N. Saha at whose suggestion these experiments were undertaken.

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RELATION BETWEEN INTENSITY AND VELOCITY OF A PHOTOCHEMICAL REACTION

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The problem of the relation between intensity and velocity of photochemical reactions is highly controversial and in this paper I have tried to throw some light on the problem, from theoretical considerations.

It is well known that the velocity of a reaction is determined by the number of active molecules present in the reacting system and that the photochemical acceleration consists in increasing this number of active molecules. Amount of photochemical acceleration at any time is therefore a factor which is dependent on the number of inactive molecules present at any instant. Greater the number of inactive molecules greater is the probability of activation. The simplest assumption would be that the same fraction of the inactive molecules is activated by equal increments in intensity.

Let us suppose that the total number of molecules present in a system is A , and the velocity v_1 in the dark is due to x , activated molecules. The number of inactivated molecules is therefore $A-x$. Let us also suppose that the velocity v_2 in light is due to z active molecules. Then clearly we have

$$\frac{dx}{dt} = v_1 \propto x$$

$$\text{and } \frac{dx}{dt} = v_2 \propto z$$

Hence the photochemical acceleration $v_2 - v_1 \propto z - x \propto A - x$.

Let us suppose that the intensity of light is varied in n equal stages and in each case the fraction y of the inactivated

molecules is activated. Then the velocity in the first stage V_1 is given by

$$\frac{dx}{dt} = V_1 \propto x + (A-x)y.$$

Velocity in the second stage is given by

$$\frac{dx}{dt} = V_2 \propto x + (A-x)y + \{(A-x) - (A-x)y\}y.$$

Thus the velocity in the n th stage is given by

$$\begin{aligned} \frac{dx}{dt} = V_n \propto & x + (A-x)y + \{(A-x) - (A-x)y\}y + \\ & [(A-x) - (A-x)y - \{(A-x) - (A-x)y\}y]y + \dots \dots \dots \\ & n \text{ terms.} \end{aligned}$$

$$\begin{aligned} \propto & x + (A-x)y + \\ & (A-x)y - (A-x)y^2 + \\ & (A-x)y - (A-x)y^2 - (A-x)y^2 + (A-x)y^3 + \\ & (A-x)y - (A-x)y^2 - (A-x)y^2 + (A-x)y^3 - \\ & (A-x)y^2 + (A-x)y^3 + (A-x)y^3 - (A-x)y^4 + \dots \dots \dots n \text{ terms.} \end{aligned}$$

$$\begin{aligned} \sim & x + (A-x)y + \\ & (A-x)y - (A-x)y^2 + \\ & (A-x)y - 2(A-x)y^2 + (A-x)y^3 \\ & (A-x)y - 3(A-x)y^2 + 3(A-x)y^3 - (A-x)y^4 + \dots \dots \dots \\ & n \text{ terms.} \end{aligned}$$

$$\begin{aligned} \propto & x + n(A-x)y - (1+2+3+\dots + \overline{n-1})(A-x)y^2 + \\ & \{1 + (1+2) + (1+2+3) + (1+2+3+4) + \dots \dots + \\ & (1+2+3+\dots + \overline{n-2})\}(A-x)y^3 \dots \dots \dots n \text{ terms.} \end{aligned}$$

coefficients of each term represents a series which can be summed up. Thus the coefficients of y^2 are

$$(1+2+3+\dots + \overline{n-1}) = \frac{(n-1)n}{2} = \frac{n(n-1)}{1 \cdot 2}$$

The coefficients of y^3 are $\{1 + (1+2) + (1+2+3) + \dots + (1+2+\dots + n-2)\}$. It will be observed that the last term of the coefficients of higher powers of y is always equal to the sum of the co-efficients of lower power of y minus the last term. There

are only $n-2$ terms in the above series, the n th term of which is $\frac{n(n+1)}{2} = \frac{1}{2}(n^2 + n)$. Thus the series is the sum of the two series

$$\frac{1}{2}\{1^2 + 2^2 + 3^2 + \dots (n-2)^2 + (1+2+3+\dots (n-2))\}.$$

Hence the sum is given by

$$\begin{aligned} & \frac{1}{2} \left\{ \frac{(n-2)(n-1)(2n-3)}{6} + \frac{(n-2)(n-1)}{2} \right\} \\ &= \frac{n(n-1)(n-2)}{1 \cdot 2 \cdot 3}. \end{aligned}$$

The coefficients of y^3 contain only $(n-3)$ terms and the sum of the coefficients of y^3 represents $(n-2)$ th term of the series the n th term of which is $\frac{n(n+1)(n+2)}{1 \cdot 2 \cdot 3}$.

Hence the coefficients of y^3

$$= \frac{1}{6} [1^3 + 2^3 + \dots (n-3)^3 + 3\{1^2 + 2^2 + 3^2 + \dots (n-3)^2\} + 2(1+2+\dots + n-3)]$$

The sum of the first series = $\left\{ \frac{(n-3)(n-2)}{2} \right\}^2$. The sum of the

second series = $\frac{(n-3)(n-2)(2n-5)}{6}$ and the sum of the

third series = $\frac{(n-3)(n-2)}{2}$.

Therefore coefficients of $y^3 = \frac{n(n-1)(n-2)(n-3)}{1 \cdot 2 \cdot 3 \cdot 4}$

Similarly the coefficients of $y^4 = \frac{n(n-1)(n-2)(n-3)(n-4)}{1 \cdot 2 \cdot 3 \cdot 4 \cdot 5}$

and so on for the higher powers of y . Finally the coefficients of y^n are given by $\frac{n(n-1)(n-2)(n-3)\dots 3 \cdot 2 \cdot 1}{1 \cdot 2 \cdot 3 \dots (n-2)(n-1)n} = 1$

Hence the final velocity V_n is given by

$$\begin{aligned} \frac{dx}{dt} = V_n &= x + n \dots (A-x)y - \frac{n(n-1)}{2} (A-x)y^2 + \dots \\ &\quad + \frac{n}{n} y^n (A-x) \end{aligned}$$

$$\begin{aligned}
& \propto x + (A-x) \left\{ -ny + \frac{n(n-1)y^2}{2} - \frac{n(n-1)(n-2)}{3}y^3 \right. \\
& \quad \left. + \dots \pm y^n \right\} \\
& \propto x + (A-x) \left\{ 1 - ny + \frac{n(n-1)y^2}{2} - \frac{n(n-1)(n-2)}{3}y^3 \right. \\
& \quad \left. + \dots \pm y^{n-1} \right\} \\
& \propto x + (A-x) \left\{ (1-y)^n - 1 \right\} = x + (A-x) \left\{ 1 - (1-y)^n \right\}
\end{aligned}$$

for $1 - ny + \frac{n(n-1)}{2}y^2 - \dots \pm y^n$ is the expansion of the binomial $(1-y)^n$

Hence the photochemical acceleration is proportional to

$$(A-x) \{1 - (1-y)^n\}$$

If the photochemical acceleration over the dark reaction is very small, and moreover y is a fraction and therefore less than unity, hence the higher powers of y , as squares, cubes and may be neglected. The photochemical acceleration is therefore proportional to

$$\begin{aligned}
& (A-x) \{1 - (1-ny)\} \\
& = n(A-x)y
\end{aligned}$$

Hence the photochemical acceleration in the n th stage or by increasing the intensity n -fold, is n times the acceleration in the first stage. That is when the photochemical acceleration is small the velocity is directly proportional to the light intensity. However when y is large higher powers of y cannot be neglected, and hence the velocity intensity relation is less than unity or approaches square root relationship.

When the absorption of the radiation is high and the reaction is not markedly photochemical in nature and the velocity of the reaction in the dark is appreciable, direct proportionality is likely to be observed. On the other hand when the reaction is highly photochemical in nature and the velocity of the dark reaction is practically negligible, square root or less than square root relationship will be expected.

Berthoud and Bellenot¹ and Briers, Chapman and Walters² have found that the reaction between potassium oxalate and iodine is proportional to the light intensity. Mukerji and Dhar³ have observed that the reaction between potassium oxalate and iodine tends to be directly proportional to the intensity of radiation of wave-length 5650.Å in absence of potassium iodide. They have observed that these radiations are only slightly absorbed by the reacting system. Bhagwat and Dhar⁴ have found that the photodecomposition of sodium cobaltinitrite is proportional to the square root of intensity in sunlight.

On the other hand Warburg and Negelein⁵ found that in the carbon dioxide assimilation process sensitised by chlorophyll, the rate of assimilation increases less rapidly than the intensity. It is well known that no combination of carbon dioxide and moisture takes place in the dark even in presence of chlorophyll and hence carbon assimilation is a typically photochemical reaction where the velocity does not increase proportionally with the intensity of light. According to Berthoud⁶ square root relation holds for addition of bromine to cinnamic acid to α -phenyl cinnamionitrile and to stilbene and oxidation of HI in presence of iodine. In all these cases the reactions are highly accelerated by light and the reaction velocity in the dark is very small in comparison with the photochemical velocity. Bodenstein and Lutkemeyer⁷ have announced that the union of hydrogen and bromine in light is proportional to the square root of the energy absorbed when the intensity of light is kept constant. It will be interesting to observe that the velocity of the same reaction taking place in the light is 300 times greater than that taking place in the dark. Consequently the combination of bromine and hydrogen is highly photochemical in nature. Briers and Chapman⁸ have recently found that the rate of interaction of hydrogen and bromine for very high intensity of light approximates to values, which are square root to the values of intensity but for low intensities, the rate becomes more nearly equal to values proportional to intensity. These results have been

recently confirmed by Bodenstein, Jost and Jung.⁹ The reactions where square root or less than square root relationship holds are largely accelerated by light and their thermal reaction velocities are extremely slow in comparison with the reaction in light alone.

Direct relationship between intensity and velocity has been found in cases of hydrolysis of chloroplatinic acids,¹⁰ the decomposition of solutions of hydrogen peroxides, potassium cobalti oxalate¹¹ and potassium manganioxalate¹² and for the initial photolysis of uranylformate solution.¹³ Now in all these cases in presence of light, the velocity of reaction is not enormously increased. Our¹⁴ conclusions have thrown a flood of light on the highly controversial question of the relation between intensity and velocity in the reaction between hydrogen and chlorine.

In conclusion my best thanks are due to Prof. N. R. Dhar for his kind interest in this paper.

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SOME PHYSICAL PROPERTIES OF CONCENTRATED HYDROXIDE SOLS

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A considerable amount of work has been done on the preparations of the hydroxide sols of Iron, Aluminium and Chromium but very little attempt has been made to prepare these in concentrated conditions. The concentration of the dispersed phase plays a very important part in determining the character of the colloids whether lyophilic or lyophobic. Freundlich¹ remarks "that a sol of $\text{Fe}(\text{OH})_3$ possesses several notable properties which can enable us to classify this as intermediate between lyophobic and lyophilic colloids." It is possible that these hydroxide sols may possess properties more closely to lyophilic colloids, if they can be obtained in very concentrated forms. Our investigations, as presented in this paper, will show that very concentrated sols remarkably alter the physical properties, especially, the viscosity and hydration which enable us to classify these as more lyophilic than lyophobic ones.

The method followed in the preparations of concentrated sols of $\text{Fe}(\text{OH})_3$ and $\text{Al}(\text{OH})_3$ was that of Weiser.² To the freshly precipitates, minimum quantities of glacial acetic acid were added until the whole of the precipitate gets peptised. These were then boiled and the excess of acetic acid was thus removed. The sols were then subjected to hot dialysis, when they were further purified. The $\text{Cr}(\text{OH})_3$ sol could not be prepared as above, so we followed a method analogous to that of Graham who prepared colloidal $\text{Fe}(\text{OH})_3$ by treating FeCl_3 with $(\text{NH}_4)_2\text{CO}_3$. To a boiling concentrated solution of CrCl_3

powdered $(\text{NH}_4)_2\text{CO}_3$ was gradually added, until a precipitate of $\text{Cr}(\text{OH})_3$ peptised with difficulty. The sol was then subjected to continuous hot dialysis maintaining the temperature at about $70^\circ-80^\circ$.

The strengths of the sols after dialysis were as given below

Substance	Amount per litre of the sol
Cr_2O_3	127 gm.
Fe_2O_3	81 „
Al_2O_3	38.4 gm.

COAGULATION OF THE SOLS BY ELECTROLYTES

Investigations on the precipitation of the dialysed and undialysed sols by the potassium salts of mono-, bi-, tri-, and quadrivalent ions were carried out. Both the $\text{Fe}(\text{OH})_3$ and $\text{Al}(\text{OH})_3$ sols could be coagulated by KCl . But it failed in the case of $\text{Cr}(\text{OH})_3$ sol. Accordingly KIO_3 was tried in this case which proved to be of bivalent character in the form $\text{K}_2\text{I}_2\text{O}_7$.³ The coagulations values of both the dialysed and undialysed sols are given below :—

Precipitation values in molar terms

Electrolytes	$\text{Fe}(\text{OH})_3$		$\text{Al}(\text{OH})_3$		$\text{Cr}(\text{OH})_3$	
	undialysed	dialysed	undialysed	dialysed	undialysed	dialysed
KCl ...	0.0976	0.03	1.42	0.5205	...	...
KIO_3 ...	...	...	...	...	0.0125	0.0075
K_2SO_4 ...	0.00145	0.0007	0.0056	0.0018	0.009	0.0055
$\text{K}_3\text{Fe}(\text{CN})_6$	0.00036	0.000242	0.0015	0.0013	0.0046	0.0036
$\text{K}_4\text{Fe}(\text{CN})_6$	0.00007	0.000048	0.0019	0.0014	0.0022	0.0006

From the above table it is clear that the precipitation values in the case of dialysed sols are considerably less than those of the undialysed ones, because with dialysis the stabilising electrolytes are removed which lessen the charge of the colloids or the sols become more sensitive towards electrolytes.⁴

To study the influence of the concentration of the dispersed phase on the stability of the sols, coagulation with more dilute sols were carried on. It was observed that the precipitation values of the monovalent electrolyte e.g. KCl, increase with dilution of the $\text{Fe}(\text{OH})_3$ and $\text{Al}(\text{OH})_3$ sols. This anomalous behavior can be explained as follows:—

The original sols more hydrated and the amount of free water in it was less than in the diluted conditions. So the dissociation of acetic acid was more in the dilute sols than in the concentrated ones. The adsorption of hydrogen ion was, therefore, more marked in the dilute state and this increased the charge on the colloid particles.

During coagulation, periodic precipitation of the coagulated mass was observed in the case of $\text{Fe}(\text{OH})_3$ sol. Prior to our observation this kind of periodic precipitation was only observed in the presence of a peptising medium like gelatin, agar, starch, glycerine, etc. We obtained rings quickly by coagulating the sols with KCl much above the precipitation values. We have found that the greater the concentration of KCl introduced in a $\text{Fe}(\text{OH})_3$ sol, the quicker is the formation of the rings and lesser their number. This ring formation depends upon the velocity of coagulation of sols by electrolytes. As is seen from the precipitation values the amount of KCl required was more in comparison to those of other electrolytes. So the velocity of coagulation was slow, and slower the velocity, the smaller the size of the coagulated particles; consequently, the size of the particles in the beginning was greater than towards the completion of coagulation. The bigger particles adsorbed the smaller ones and formed zones where the concentration of the coagulum was high, and hence more clear spaces were formed above and below the zones.

VISCOSITY

When the sols were subjected to hot dialysis, the increment in concentration was negligible in comparison to the increments in viscosity, so much so that further dialysis transformed the sols to jelly-like substances. As for example, undialysed $\text{Cr}(\text{OH})_3$ sol had the concentration of 109 gms. of Cr_2O_3 per litre and the viscosity only 2.19 (taking viscosity of water as one) but the dialysed sol had the concentration of only 127 gms. and the viscosity rose as much as 1643 times that of water. It is due to the fact that with dialysis the charge on the colloid particles gradually decreased and this decrease in electric charge caused an increase in hydration and necessarily in the viscosity of the sol. During dialysis, the stabilising electrolyte was gradually taken away and the colloid particles due to their charge inherent in them, adsorb water in molecular layers, until all the electrical energy was thus bound up by the different layers. The mobility of the colloid particles decreased by entangled layers of water. Thus we may generalise that the greater the hydration, the greater the viscosity. To study the change in viscosity with dilution of the sols, viscosities at different dilutions were measured. The applicability of the viscosity concentration equations given by several investigators was tried. Only S. Arrhenius' empirical equation, e.g. $\log \eta = \theta C$, where η = viscosity of the dispersed phase, θ = constant, C = molar concentration, was applicable here. The adjoining graphs show that the viscosity concentration curves are logarithmic. These kinds of logarithmic curves were obtained by other investigators with the organic sols like gelatine agar, cellulose nitrate, etc. So we conclude as far as the important property, viz., viscosity is concerned that the concentrated sols of $\text{Fe}(\text{OH})_3$, $\text{Al}(\text{OH})_3$, $\text{Cr}(\text{OH})_3$ behave as lyophilic colloids.

REVERSIBILITY

An interesting phenomenon observed in the case of these hydroxide sols was that these viscous sols could be dried and the dry mass could again be peptised in cold water giving

clear sols. Uptil now this reversibility was only observed with the lyophilic colloids, namely gelatine, agar, etc. This reversibility was prominent with $\text{Cr}(\text{OH})_3$ sol and least with the $\text{Fe}(\text{OH})_3$ one. The dry masses were analysed and the analysis with dry $\text{Cr}(\text{OH})_3$ sol is given below :—

Constituents	% Composition
Cr_2O_3	44.18
Cl	15.1
Water	42.8

The formula derived from the percentage composition in the usual way is $\text{Cr}_3(\text{OH})_{12}\text{Cl}_3 \cdot 28\text{H}_2\text{O}$. Bjerrum⁶ claimed to have obtained the basic salts of chromium as $\text{Cr}(\text{OH})_2\text{Cl}$ and $\text{Cr}(\text{OH})\text{Cl}_2$. But there is no mention in the literature, that there is salt as basic as $\text{Cr}_3(\text{OH})_{12}\text{Cl}_3 \cdot 28\text{H}_2\text{O}$. Moreover by splitting the formula as $[\text{Cr}(\text{OH})_3 \cdot 7\text{H}_2\text{O}]_4 \cdot \text{CrCl}_3$, it is quite clear that there is CrCl_3 associated with every 4 molecules of $\text{Cr}(\text{OH})_3 \cdot 7\text{H}_2\text{O}$ and each molecule of $\text{Cr}(\text{OH})_3$ is associated with seven molecules water of hydration. This kind of reversibility is probably due to the fact, that while being dried, the aggregate of the sol particles which were originally highly hydrated, came nearer as the dispersion medium gradually evaporated, until the water layers surrounding the particles touched one another and these set in regular layers. When this dry mass was put in water the latter entered into it and the adsorbed electrolyte in the dry mass could peptise the whole mass giving us a clear sol.

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THE OCCURRENCE OF FATTY TUMOURS IN PIGEONS (*COLUMBA INTERMEDIA* STRICKL)

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In pigeons that are commonly obtained for dissection at Allahabad, I often observed, during the course of demonstration, the presence of tumours grown either on the pectoral muscles, or on the leg, or on the backbone of the bird. I dissected out these tumours and always found them to contain fat and fibrous tissue—there being no larvæ of any Helminth inside them showing that they were not of parasitic origin.

Some time ago, I chanced to obtain one pigeon which was badly suffering from extraordinary overgrowth of fatty tumours. At the time I obtained it, the bird was leading a dull precarious life. The photograph of the bird shows how greatly it is handicapped owing to the extensive growth of tumours. The right eye is practically destroyed, its ruinous state being brought about by the malignant growth, and all over the body particularly on the head and the face there are countless tumours of varied size. Judging from the external outlook one should expect the visceral organs to have been similarly affected. I find the heart is by far the most diseased of all the internal organs. The heart is relatively small in size and between it and the pericardium there is a considerable amount of fat-deposit. The liver, the pancreas and the gizzard have also undergone a partial fatty degeneration. The degeneration of the tissue of the internal organs is evidently caused by metabolic disorder which has brought about accumulation of fat.

Microscopically the structure of a tumour shows degeneration of cells and fibrous connective tissue with abundant deposit of fat.

Previous Works.—Apart from illness caused by Helminths and Mites, lower vertebrates are seldom found to be suffering from disease. Usually, they are seized and devoured by some predaceous animals. Nevertheless tumours, cysts and pathological conditions are occasionally met with and reported. Southwell and Prasad '19 (7) describe tumours occurring all over the surface of the body of a climbing perch (*Anabas scandens*) kept in artificial condition. In this case the tumour consists of a tissue of a "Thyroid nature." Johnstone '15 (3) refers to a number of piscine sarcomata and particularly to multiple tumours in halibut and cod. The halibut was suffering from multiple melanotic sarcomata. The cod showed a large sarcomatous tumour undergoing profound degeneration with deficient vascular supply.

A condition of rare occurrence is described by Williamson '19 (9). A hard spherical tumour projecting from the right maxilla of a cod was found to contain a bony capsule inside which there were several hundreds of teeth.

The toxic and tumour producing properties of various parasites such as *Filaria bancrofti*, *F. medinensis*, *F. rhytipleuritica*, *Dibothriocephalus latus*, *Bilharzia haematobia*, and various mites as for example *Phytoptus*, *Tarsonemus*, *Notoedres*, have been studied by Saul '13 (6). Ludford '25 (5) has studied the cytology of tumours produced by painting the skin of mice with tar. The cell-hypertrophy is of common occurrence. Kreyburg '25 (4) has examined the cell structure of tar tumours of the skin of white mice and has observed the epithelium to be most atypical and undifferentiated.

Boveri '14 (1), in 1902, suggested that tumours might be the result of an abnormal condition of chromosomes, as for instance in pleuropolar mitosis. Aichel has sought to combine this suggestion with another, that the beginning of the tumour may be coalescence of a leucocyte and a tissue cell. Dungern and Werner '07 (2) have put forward a theory of tumours. According to them all cells have in themselves several regulating factors or mechanisms which inhibit a persistent increase of the growth and multiplication. By various

stimuli these inhibitory arrangements may be temporarily put out of order so that exaggerated assimilation and proliferation set in.

Tumours are produced by fatty degeneration of tissue cells brought about by metabolic toximia, and also by local irritation such as painting of skin with tar. Helminth and Acarid parasites, Gregarines or other micro-organisms must be taken into consideration in the aetiology and growth of tumours.

I should acknowledge here my sincere thanks to Professor D. R. Bhattacharya for helpful criticisms.

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Fig. 1.—Photograph of the pigeon showing extensive growth of tumours on the head and body. The right eye is practically destroyed by the over-growth of tumours.

PHOTOSENSITISED OXIDATION OF AMMONIA AND AMMONIUM SALTS AND THE PROBLEM OF NITRIFICATION IN SOILS

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Received March 18, 1931.

Most plants get the nitrogen, they require, from the soil where it is present in the form of nitrates, ammonium salts or other complex nitrogenous compounds. Ammonium salts and other nitrogenous compounds must first be oxidised to nitrites and nitrates before they can be utilised by the plant. It has long since been known that ammonia and ammonium salts are oxidised in the soil to nitrites and nitrates. It is now universally believed that the nitrification in soils is due entirely to the action of bacteria. The biological character of the nitrification process was first shown by Schlosing and Muntz.¹ From the painstaking researches of Warington, Frankland and Winogradsky, we now know that this nitrification is really due to the joint action of two organisms: one converts ammonium salts to nitrites and the other brings about the oxidation of nitrite to nitrates but has no effect on ammonium salts.

From our experiments on the photosensitised oxidation of ammonia and ammonium salts in the presence of sunlight and various photosensitisers like titania, zinc and cadmium oxides, sodium uranate, alumina and silica, we are confident that the nitrification in the soil is, at least in part, photochemical in nature taking place at the surface of various photosensitisers under the influence of sunlight. In the absence of sensitisers there is a noticeable, though very slight, oxidation.² It has been noted by Berthelot³ that the same reaction takes place in

ultraviolet light. Under the action of sunlight and in the presence of sensitisers, there is vigorous oxidation of ammonia and ammonium salts to nitrite.

EXPERIMENTAL

The photosensitisers employed are titania, zinc oxide, cadmium oxide, sodium uranate, alumina and silica. They were prepared by precipitation from the aqueous solutions of the corresponding pure salts (Merck's or Kahlbaum's). They were usually dried, ignited and finely powdered. The freshly precipitated substances were also tried, but these, as a rule, are less active than the ignited materials. For example, freshly precipitated and hydrated zinc oxide is less active than the ignited zinc oxide. It is also significant that neither clear saturated solutions of zinc oxide nor solutions of zinc salts possess any photo-sensitising activity. The insoluble solid oxides only are active.

The method employed usually consisted in exposing solutions of ammonia or ammonium salts to sunlight with small quantities of the photosensitiser and a current of air free from nitrous fumes was passed through the solutions, so that the solid photocatalysts were kept in suspension. Glass beakers were generally employed; and as glass transmits only up to 3500 Å it may be concluded that radiations of wavelength less than 3500 Å, do not take part in our reactions. In all the cases studied there is no dark reaction.

Qualitatively nitrite was tested for by the Griess reagent and starch potassium iodide; quantitatively it was estimated by the usual permanganate method.

Influence of P_{H_2} .—To study the influence of P_{H_2} on the rate of oxidation, each time 100 c.c. of N/5 solutions of aqueous ammonia, ammonium carbonate, ammonium phosphate, ammonium chloride and ammonium sulphate solutions were taken in pyrex glass beakers, 1 gm. of Merck's zinc oxide added and exposed to the sun for 3 hours while a current of air was passed through at an approximately uniform rate. The beakers were

always covered with glass plates. The resulting nitrite was estimated by the permanganate method, which necessitated the use of manganous sulphate whenever there was chloride present.

The results are as follows:—

Table 1

Salt solution used.	Volume of N/40 KMnO_4 solution corresponding to the amount of nitrite formed.	Amount of nitrite formed per liter of solution in grs.
NH_4OH ...	7.1 c. c.	.000875
$(\text{NH}_4)_2\text{CO}_3$...	3.0 c. c.	.000375
$(\text{NH}_4)_2\text{HPO}_4$...	2.0 c. c.	.000230
$(\text{NH}_4)_2\text{SO}_4$...	2.4 c. c.	.000300
NH_4Cl ...	2.0 c. c.	.000230

[100 c. c. of N/5 salt solution. Time of exposure to the sun—3 hours.]

From the foregoing results anions do not seem to have much influence on the rate of oxidation. The P_H of the solution seems to have a great influence on the rate of oxidation. So the P_H values of N/5 aqueous solutions of the above salts were determined.

Table 2

Salt solution.	P_H
NH_4OH	above 10
$(\text{NH}_4)_2\text{CO}_3$	8.1
$(\text{NH}_4)_2\text{SO}_4$	6.9
$(\text{NH}_4)_2\text{HPO}_4$	8.0
$(\text{NH}_4)\text{Cl}$	6.9

On the whole, acidity seems to decrease the rate and basicity to speed up the rate of oxidation; though an exception to this rule is noticed in the case of ammonium phosphate. This case requires further investigation.

Comparative experiments in glass and quartz vessels.—

The rate of oxidation is greater in a quartz vessel than in a glass one, as the following results show:—

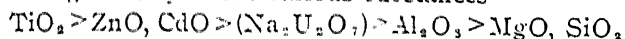
	Volume of N/40 KMnO_4 solution correspond- ing to the nitrite formed.
100 c.c. of N/5 aqueous ammonia exposed in a <i>glass beaker</i> for 3 hours with 1 gram of ZnO .	7.1 c.c.
100 c.c. of N/5 aqueous ammonia exposed in a quartz beaker for 3 hours with 1 gram of ZnO	11.0 c.c.

This fact can be easily explained as follows:—Zinc oxide shows marked absorption in the blue, violet and ultraviolet regions of the spectrum. In sunlight, at least in tropical countries, the ultraviolet region extends to 2900 \AA . Now when the experiment is carried on in a glass vessel, only radiation up to 3500 \AA can be utilised, because glass does not transmit beyond this region—whereas in a quartz vessel all the radiations in the solar spectrum up to 2900 \AA can be utilised. Evidently more of the solar energy is utilised in a quartz vessel than in a glass vessel; and hence the greater rapidity of the reaction.

The accumulation of nitrite seems to have little or no influence on the rate of oxidation of ammonia.

Comparative activities of the various photosensitisers.—

Semi-quantitative experiments, the results of which are not recorded here, indicate the following order for the photosensitising activity of the various substances

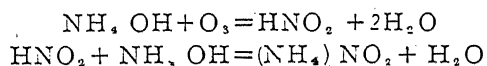


We hope we will be able to elucidate the varying activity of these substances from a study of their absorption spectra.

MECHANISM OF THE OXIDATION

A discussion of the mechanism of photosensitisation by these metallic oxides will be out of place here. But we propose

only to discuss by what mechanism ammonia and ammonium salts are oxidised to nitrite. According to Winther⁴ oxygen can be ozonised in presence of zinc oxide by irradiation with light of wavelengths which will have no action on oxygen alone. We have found that when a suspension of zinc oxide in water is exposed to sunlight, ozone and hydrogen peroxide are formed. It is known that ozone interacts with ammonia or ammonium salts according to the equation



and the nitrous acid interacts with ammonia giving ammonium nitrite.

DISCUSSION

These experiments on the photochemical oxidation of ammonia and ammonium compounds to nitrite are remarkably interesting from the point of view of the nitrification in soils. Hitherto it is believed that the nitrification is entirely due to bacteria. We are now convinced that it is, at least in part, photochemical in nature taking place at the surface of various soil photocatalysts which absorb the solar radiations. There are some important facts of the nitrification process which do not fit in with the bacterial hypothesis. The advantage of the present hypothesis consists in that it not only accounts for these facts inexplicable on the older hypothesis, but is also in a line with other facts of the nitrification in soils.

The following are some of the important facts inexplicable on the bacterial hypothesis:—

(1) Omeliansky⁵ and Meyerhof⁶ have shown that for the bacterial nitrification process a high concentration of ammonia or nitrite is harmful—the optimum concentration is about 0.05 % with a second optimum at 0.1 %. Over 0.3 % interferes with the process. In certain localities, the so-called nitrite-spots, a high concentration of nitrite and nitrate as much as 5% of the bulk of the soil has been noticed. The biological explanation cannot be entirely sufficient for the accumulation

of nitrites and nitrates, for the high concentration of nitrite and nitrate formed should preclude the action of nitrifying organisms in the later stages.

(2) The researches of Traaen⁷ McBeth and N. R. Smith⁸ and Kelley⁹ have shown that the nature of the soil is also of influence on the nitrification.

(3) A periodic variation of the nitrite and nitrate content of soils has been noticed by several workers (Compare Batham, Report of the Indian Science Congress, 1930, Agricultural Section). The nitrite and nitrate content of soils rises to a maximum in the summer and falls to a minimum in the winter. These results are explained by some as being due to the activating influence of the sun on the nitrifying bacteria. How far this is true cannot be said with certainty at present, but our photochemical hypothesis offers a ready explanation of this phenomenon.

The above facts can be explained as follows:—

(1) We have shown that the oxidation of ammonium compounds to nitrite takes place at the surface of various oxides, *e.g.*, titania, zinc oxide, cadmium oxide, alumina and silica in the presence of sunlight. We have also shown that the accumulated nitrite has no influence on the rate of oxidation of ammonium compounds. In the soil alumina and silica and also titania, undoubtedly occur. The photochemical hypothesis thus sets no limit to the amount of nitrite that can be formed. As such the accumulation of nitrites and nitrates in large amounts in the nitre spots is explained.

(2) The influence of soils and the varying activity of different soils also finds a ready explanation on this hypothesis. All soils contain alumina and silica; all soils are therefore more or less active for the nitrification process. It has been found that titania, zinc and cadmium oxides are very efficient photocatalysts for the nitrification process, far more active than alumina and silica. So if the soil contains in addition to alumina and silica, titania, or zinc and cadmium oxides or some other efficient photocatalyst as yet undiscovered, it will be very active in the nitrification process and hence very

fertile. In consonance with this presumption it has been recorded by Geilman¹⁰ that most fertile soils contain titania in quantities as large as 0.3–0.6%. It also occurs in the ashes of all plants up to 0.27%. According to the same worker, the fertility of the soil depends to some extent on the titanium content of the soil.

The observations made in the present investigation that basicity favours the photochemical oxidation and acidity is harmful are in agreement with similar observations on the nitrification process in the soil by various workers.

Besides the evidence so far adduced in favour of the photochemical hypothesis, the following also may be mentioned. St. von. Bazarewsky¹¹ Koch¹² and Kelley¹³ and co-workers have found that the nitrification process is most active near the surface of the soil. This observation forms a necessary deduction of our photochemical hypothesis, for most of the light falling is absorbed by the outermost layers of the soil and little is allowed to pass through. As light is essential for the photochemical nitrification, it is but natural that there is the greatest oxidation where there is the maximum absorption of radiant energy.

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VITAL STAINING EXPERIMENTS IN SCYLLA SERRATA (FORSK)

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Communicated by Prof. D. R. Bhattacharya.

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INTRODUCTION

A little over 30 years ago, Camillo Golgi¹ for the first time described the "Apparato reticulare interno" in the cytoplasm of the Purkinje cells of the cerebellar cortex of the brain of the owl. A few months later he found the same apparatus in the spinal ganglion cells of a number of vertebrates. Golgi's pupils and successors carried out experiments in other kinds of cells and were able to demonstrate the presence of this apparatus which now bears his name. Since this discovery the apparatus has now been described practically in all kinds of somatic and germ cells.

The methods applied for demonstrating the Golgi apparatus and other cytoplasmic inclusions fall under two heads. Firstly, the examination of the material fixed by the classical methods as described in the *Vade Mecum* by Cowdry and Gatenby,² and secondly, the vital and post-vital examination of fresh material with the aid of vital dyes. It is the latter method which I am dealing with in this communication.

Vital staining methods have come into vogue during the last ten years. They consist in (i) injecting a dye into the body of the living animal, (ii) staining and examining the tissue under the microscope in the fresh condition. These vital staining experiments have been performed by Gatenby, Möllendorff, Parat, Ludford, Bhattacharya, Vishwanath, Mukerji, Bowen and others. Various dyes such as neutral red,

Janus green B, methylene blue, Trypan blue, Nile blue, etc. have been recommended to stain the various inclusions, in the fresh material. The most successful results so far obtained have been with Grubler's neutral red and Janus green B in very dilute solutions. Parat³ with his collaborators, for the first time, demonstrated the occurrence of Vacuome in the animal cells by the vital colouration methods and came to the conclusion that the Golgi apparatus and the Vacuome were homologous structures. It was not long before the claim was disputed, firstly, by Avel,⁴ and later on by Gatenby,⁵ Bowen,⁶ Das and Bhattacharya.⁷ Beams and Goldsmith⁸ in the salivary glands of *Chironomus* larva have pointed out that the Golgi apparatus and the Vacuome are quite different structures and that possibly the Vacuome is an aggregation of secretory products of Golgi elements. Bhattacharya and Das have also pointed out that in the pigeons the Vacuome and the Golgi bodies are quite distinct and separate structures. Gatenby and Mukerji⁹ in the male germ cells of *Lepisma* have proved conclusively that the Golgi bodies and the Vacuome lie in close relationship with each other and can in no way be said to be homologous structures.

OBSERVATIONS

The crabs were fed with grains of neutral red dye but unfortunately this method proved toxic and the animals invariably died within a day or two. Ovaries were taken out from the living animals and placed in physiological salt solution immediately for purposes of examination. All precautionary measures to avoid post mortem changes as recommended by Gatenby in the *Vade Mecum* were scrupulously observed. Pieces of ovaries were then transferred to 1/25,000 dilution of neutral red as recommended by Bhattacharya and Das. Within half an hour the "Vacuome" get prominently stained and the Golgi bodies show themselves as greyish black structures quite separate and distinct from the red patches of Vacuome. The addition of a few drops of osmic

acid makes the Golgi bodies slightly more distinct but leaves the Vacuome unaffected. Some swollen up Golgi bodies appear to take a darker colour and these are identified as fatty yolk spheres. It may be noted here that unless a dilute solution of neutral red is used (the strength of which cannot be fixed but varies in different animals), the results may not be successful. Only repeated experiments can tell what particular strength of the dye will suit a particular case. In this animal the "Yolk nucleus of Balbiani" area forming a cap-like investment can be seen distinctly even without the aid of any dye. Therefore there is no doubt that this archoplasmic area containing cytoplasmic inclusions exists in young eggs. In older oocytes this area disappears and the bigger patches of Vacuome disintegrate "pari-passu" with the dispersal of the Golgi bodies from this area into the general cytoplasm.

CONCLUSION

The result of the observations in this animal leads me to the conclusion that the Golgi bodies and Vacuome while lying side by side are distinct and separate structures. Since they can be brought into view at the same time with the aid of neutral red and osmic acid, there is no reason to consider them as homologous structures. Criticisms along these lines in the case of other animals have already been advanced by Bhattacharya and Das, Gatenby and Mukerji and others. Parat has tried to show that the Golgi crescents or Lepidosomes, as he calls them, are a kind of modified chondriosomes. This view has met with even greater opposition from Gatenby, Bhattacharya and Bowen. Parat himself claims that neutral red is specific for Vacuome or Golgi bodies and Janus green B for Mitochondria. The fact that the neutral red staining brings into view his Lepidosomes or the Golgi bodies of classical workers conclusively shows that these structures could not be, according to Parat's own arguments, mitochondrial structures of any kind whatsoever. I therefore hold that in this animal at least the Golgi bodies and Vacuome are discrete structures and not homologous with one another.

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ON SYSTEMS OF CURVES ON A RING-SHAPED SURFACE

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(ABSTRACT)

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The paper gives a new method for dealing with differential equations of the first order on a ring-shaped surface. The problem, as formulated by Poincaré, is equivalent to the study of a non-singular differential equation

$$\frac{dx}{f(x, y)} = \frac{dy}{g(x, y)},$$

where f and g are periodic of period 1 both in x and in y . Poincaré studies the problem under the assumption that f does not vanish. The present method is not restricted to that case.

C being a solution of (E), $C(p, q)$ is defined as the curve deduced from C by the translation (p, q) : if p, q are integers, this is again a solution. By observing that two solutions cannot intersect, and by studying the relative positions of the curves $C(p, q)$ for all integral values of p, q , various results are obtained, e.g.—

1. There is a number μ such that $C(p, q)$ is on one or the other side of C according as $q - \mu p$ is $>$ or < 0 .

2. $\frac{y}{x}$ tends to the limit μ when (x, y) goes to infinity along C .

3. If μ is equal to a rational number n/m , (E) has a solution which is transformed into itself by the translation (m, n) .

4. If μ is irrational, there is a continuous function $\tau(x, y)$ which takes the value $q - \mu p$ on $C(p, q)$ and satisfies the functional equation

$$\tau(x+r, y+s) = \tau(x, y) + s - \mu r \quad (r, s = \text{any integers}).$$

5. If τ is not constant in any area, the structure of the system of curves defined by (E) is completely determined by the value of the "rotation number" μ .

Reference

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THE ORIGIN OF NITRIC NITROGEN IN THE ATMOSPHERE

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Communicated by Prof. N. R. Dhar

Received August 13, 1931

INTRODUCTION

In a previous communication, a new aspect of the problem of nitrification in soils has been described. It has been found that aqueous solutions of ammonia and its salts are readily oxidised to nitrite in the presence of sunlight and photo-sensitisers like titanium dioxide, zinc oxide, cadmium oxide, sodium uranate and alumina. The same oxidation can, however, take place under the influence of the short wave ultraviolet light even in the absence of photo-sensitisers. On the basis of these experimental observations the view has been given out that nitrification in soils must be partly due to the photochemical action of sunlight. This view is capable of successfully accounting for some of the facts of soil nitrification which do not fit in with the usual bacterial explanation.

In the present paper the author will examine the nitrification in the atmosphere and the origin of nitric nitrogen therein from the photochemical point of view. The atmosphere is specially suited for this purpose, as it excludes the disturbing influence of nitrifying bacteria. As such the photochemical action, if there be any, will be predominant,

CRITICISM OF THE EXISTING VIEWS AS TO THE ORIGIN OF NITRIC NITROGEN

Nitric nitrogen occurs in the atmosphere to an appreciable extent. It occurs either as the oxides N_2O_3 , and N_2O_5 , or as ammonium nitrate and nitrite. These are washed down to the earth by the rain and form an important source of nitrogenous

food for the plants. What is the origin of this nitric nitrogen? It has been thought that oxides of nitrogen owe their origin to thunderstorms in the upper air, when due to the electric discharges taking place nitrogen and oxygen combine to form N_2O , and N_2O_3 . But be it as it may, thunderstorms do not occur often, they are the exception rather than the rule. If the oxides N_2O , and N_2O_3 are to be ascribed to the thunderstorms, they are to be washed down to the earth by the rain which follows, and there ought to be practically nothing of them left on ordinary days. But this does not hold to be good. One may test the air on ordinary days and one is sure to find oxides of nitrogen in quantities which do not differ much from that found on days when there were thunderstorms. There is no correspondence between the variation of the nitrite and nitrate content of the atmosphere and the incidence of thunderstorms. On the other hand, Moore¹ casually suggested that the oxides of nitrogen owe their origin to the photochemical combination of nitrogen and oxygen under the influence of sunlight. But he has not adduced much evidence, in support of his contention. The view of Moore also appears to be untenable; as no appreciable combination of nitrogen and oxygen occurs even under the influence of the ultraviolet light from a quartz mercury vapour lamp as shown by the experiments of M. Berthelot.²

THE AUTHOR'S VIEW

The author of the present communication would suggest the following explanation for the origin of nitric nitrogen in the atmosphere:—Briefly stated his view is that the nitrates and nitrites in the atmosphere are derived from the photochemical oxidation of ammonia under the influence of sunlight. Ammonia occurs in the atmosphere to an appreciable extent in the atmosphere; this ammonia is derived from the nitrogenous putrefaction on the surface of the earth. This ammonia is continuously undergoing oxidation to nitrate and nitrite under the influence of the short wave radiation from the sun. That this photochemical action actually takes place has been shown

by M. Berthelot and others working with quartz mercury vapour lamp. I have also been able to effect the slow oxidation of ammonia solutions in the light of a quartz mercury vapour lamp, or a copper arc. The reaction also takes place in the light filtered through a 0.5% quinine sulphate solution of 4 cm. thickness which cuts off wavelengths less than 4200 Å. Furthermore I have also observed that the oxidation takes place in sunlight in quartz or glass vessels slowly.

The author's photochemical explanation of the origin of nitric nitrogen of the atmosphere receives support from the following considerations:

1. VARIATION OF THE PROPORTION OF OXIDES OF NITROGEN AT VARIOUS ALTITUDES OF THE ATMOSPHERE

If my view of the origin of nitrates and nitrites is correct then it is necessary that the nitric nitrogen content of the atmosphere should be greater at high than at low altitudes, because the proportion of ultraviolet radiation from the sun is greater at high than at low altitudes. This will be seen to be the case from a study of the results of Hayhurst and Pring³. These workers find that the proportion of nitrous acid is greater at high than at low altitudes. The ratio of the oxides of nitrogen in the upper air to that in the lower atmosphere was found to be 2.23 : 1 at 8500 feet elevation and 1.76 : 1 at 2600 ft. elevation.

2. SEASONAL VARIATION OF THE NITRIC NITROGEN CONTENT OF THE ATMOSPHERE

As there is a seasonal variation of the intensity of solar energy in any one locality it follows from my views that there should be a corresponding variation in the nitric nitrogen content of the atmosphere. This corollary is also borne out by experiment. Thus Bineau⁴ made the following observations at Lyons.

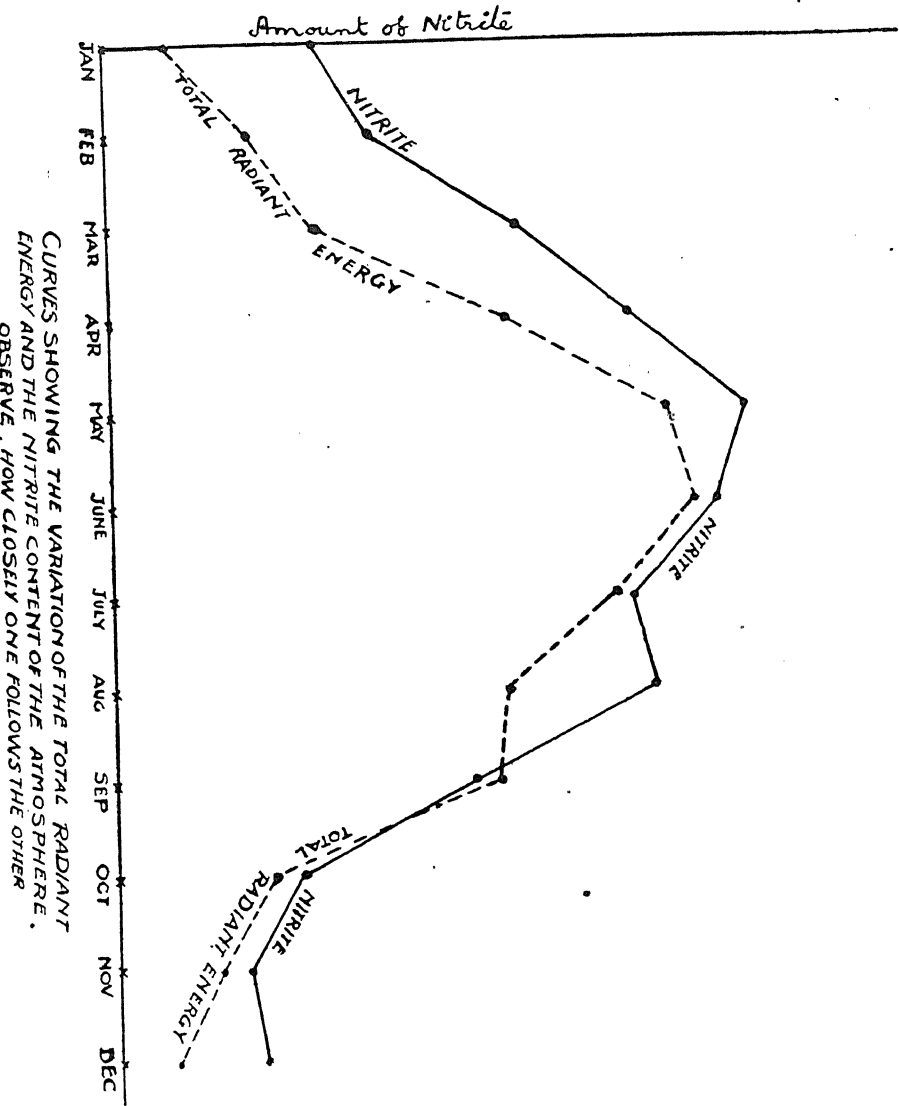


Table 1

Season	Nitric Nitrogen in m. gms. per litre of rain.		
Winter	0'30
Spring	1'00
Summer	2'00
Autumn	1'00

The maximum solar activity occurs during the summer and the minimum during the winter; accordingly the proportion of nitric nitrogen content of the atmosphere is maximum in the summer and minimum in the winter. Further, the figures for autumn and spring are the same and both of them are greater than the winter figure and less than the summer one, because, the two seasons are equinoctial and the earth receives nearly the same measure of solar energy which is greater than that received during the winter and less than that received during the summer.

Figure 1 shows two curves. One shows the variation of the total radiant energy from month to month; the other curve shows the variation of the nitrite content of the atmosphere during the twelve months of the year. Such curves were drawn for the first time by Moore¹.

Observe how closely one curve follows the other. From winter to summer the amount of nitrite is on the rise, while from summer to winter it is on the decline, corresponding exactly to the changes in the intensity of sunlight. Here the changes in nitric nitrogen follow very closely the changes in the intensity of sunlight, more closely than in the case of the soil, for in the atmosphere there is no interfering agency as the bacteria. In the soil nitrification is due to two agencies, viz., the bacteria and sunlight, whereas in the atmosphere the nitrification is due only to the photochemical action of sunlight.

3. VARIATION OF THE NITRIC NITROGEN CONTENT OF THE AIR WITH LATITUDE

As the length of day and intensity of sunlight are much greater in tropical countries than in temperate ones it will be

expected on the author's theory that the proportion of nitric nitrogen in the rain of tropical countries will be much higher than that of the rain of temperate climes. Thus, Muntz and Marceno³ found at Caracos, Venezuela in the tropics (latitude $10^{\circ}3'N$) a mean value of 2.23m. gm. of nitric nitrogen per litre of rain water, the mean value obtained by Boussingault Liebfrauenberg, Alsace, in the temperate zone was 0.19 m. gm.; that obtained by Warrington at Rothamsted, England, is 0.125 m. gm. of nitric nitrogen per litre. It is, therefore, obvious that the proportion of nitric nitrogen in rain water is much greater in tropical countries than in temperate zones.

Besides, the ratio of nitric to ammoniacal nitrogen is greater in tropical countries than in the temperate and frigid zones. Clarke⁴ obtained the following results where the data are expressed in pounds per annum.

Table 2

Place	Zone	Nitric Nitrogen	Ammoniacal Nitrogen	$\frac{\text{Nitric Nitrogen}}{\text{Ammoniacal Nitrogen}}$
British Guiana	Tropics ...	1.886	1.006	1.874
Barbados ...	" ...	2.443	1.009	2.322
Rothamsted ...	Temperate	1.130	1.710	0.419
Kansas (U.S.A.)	" ...	1.060	2.630	0.403
Iceland ...	Frigid ...	0.263	0.802	0.327

It will be seen from the above table that nitric nitrogen is usually in excess of ammoniacal nitrogen in the case of tropical countries but the converse is true of temperate and frigid zones.

SUMMARY

1. The existing view that all the nitric nitrogen of the atmosphere owes its origin to thunderstorms has been shown

to be untenable; the nitric nitrogen derived from this source can only form a small and negligible fraction.

2. A new explanation for the origin of nitric nitrogen has been given: The ammonia existing in the atmosphere is photochemically oxidized to nitrite and nitrate by air in the presence of the short wave ultraviolet regions of solar spectrum. This view fits in with the following observations—

- (a) the proportion of nitric nitrogen in the atmosphere is greater at high than at low altitudes.
- (b) there is a seasonal variation of the nitric nitrogen content of the air, the maximum occurs in the summer and the minimum in the winter.
- (c) the proportion of nitric nitrogen of rain water is much greater in tropical countries than in the temperate regions.
- (d) the ratio of nitric to ammoniacal nitrogen of the air is much greater in tropical countries than in temperate and frigid zones.

In conclusion, the author wishes to express his thanks to the Andhra University and the Kistna District Board for the award of a fellowship and to Prof N.R.Dhar, D.Sc. (London and Paris), F.I.C., etc, for his kind interest in the work.

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THE ABSORPTION SPECTRUM OF SULPHUR DIOXIDE

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Communicated by Prof. M. N. Saha

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Not much work has been done yet on the analysis of the electronic terms in the spectra of polyatomic molecules excepting some attempts by V. Henri and his associates.¹ In some works² only the lines and bands have been enumerated and in others, attempts have been made to find some regularities but no attempt has been made to trace these to any definite quantum transitions.

The present paper deals with the analysis of the sulphur-dioxide bands with regard to the vibrational quantum transitions. The fine structure analysis of the rotational transitions has not been attempted. It is important to notice in this connection that the electric moment of the SO_2 molecule has been found to be 1.61,³ thus giving support to the triangular model for its constitution. Also work on Raman effect⁴ and on infra-red spectra⁵ have indicated a strong fundamental frequency of 1152 cm^{-1} , and other frequencies of comparatively weaker intensities. We can, therefore, expect that there are more than one way of vibration in the molecule, having different fundamental frequencies and perhaps $\nu=1152 \text{ cm}^{-1}$ would be one of these. A frequency difference of about this value was, therefore, sought for in the observed bands. The trial was successful and a frequency difference of 1159 cm^{-1} was found. Another frequency difference of about 1510 cm^{-1} has been observed.

Bands have been observed in the region $\lambda 3400 \text{ \AA}$ to $\lambda 2800 \text{ \AA}$, the bands near the short-wave-end being diffuse, as has also been noticed by Victor Henri in his paper on formaldehyde.⁶

Different stages of pressure were required to bring out the whole series of bands in different plates. Pressures greater than that of one atmosphere, however, were not used. The total number of the recorded bands with their frequencies are given in Table 1 below. It is apparent that accurate values for the heads of the bands have not been obtained as no rotational analysis of the bands has been undertaken. The wavelength corresponds to the most intense part of each of the bands, which are all quite narrow.

Table 1.—Wavelengths and frequencies of the observed bands

λ	$\nu_{\text{vac.}}$	λ	$\nu_{\text{vac.}}$
2849	35090	3103	32217
2862	34930	3124	32001
2883	34676	3183	31408
2903	34437	3194	31299
2920	34237	3208	31168
2933.6	34077	3224	31008
2955	33831	3233	30922
2975.5	33598	3256	30703
2995	33379	3279	30488
3014.5	33158	3291	30377
3037	32918	3305	30249
3059.7	32673	3327	30048
3082.5	32437	3340	29931
		3355	29798

The general equation for the representation of the band heads is an extension of the formula for the diatomic molecules with two modes of vibration and is taken as

$$\begin{aligned} \nu_h = & \nu_e + (\alpha'n' + \beta'n'^2) - (\alpha''n'' + \beta''n''^2) \\ & + (\gamma'p' + \delta'p'^2) - (\gamma''p'' + \delta''p''^2) \\ & + \dots \end{aligned}$$

γ and p denoting the vibration frequency and the quantum number corresponding to the second way of vibration. The regularities that have been obtained from amongst the band heads are shown in the following Table 2;—

Table 2.—Regularities in the observed bands

33163 (216)	[1162]	32001 (216)	[1513]	30488 (215)
33379 (219)	[1162]	32217 (220)	[1514]	30703 (219)
33598 (233)	[1161]	32437 (236)	[1515]	30922 (241)
33831 (246)	[1158]	32673 (245)	[1510]	31163 (245)
34077	[1159]	32918	[1510]	31408

Having regard to the fact that $\Delta\nu 1152 \text{ cm}^{-1}$ is one of the fundamental frequencies and that the heads should be represented by the composite formula given above the only plausible quantum assignment for the bands are as shown in the following table.

Table 3.—Assignment of quantum numbers

Initial→ Final↓	$n''=0, p''=0$	Initial→ Final↓	$n''=1, p''=0$	Initial→ Final↓	$n'=1, p''=0$
$n'=1, p'=0$	33163	$n'=1, p'=0$	32001	$n'=0, p'=0$	30488
$n'=1, p'=1$	33379	$n'=1, p'=1$	32217	$n'=0, p'=1$	30703
$n'=1, p'=2$	33598	$n'=1, p'=2$	32437	$n'=0, p'=2$	30922
$n'=1, p'=3$	33831	$n'=1, p'=3$	32673	$n'=0, p'=3$	31163
$n'=1, p'=4$	34077	$n'=1, p'=4$	32918	$n'=0, p'=4$	31408

It is evident from the above that we get $\alpha'' + g'' = 1159 \text{ cm}^{-1}$ and $\alpha' + g' = 1510 \text{ cm}^{-1}$ whereas ν' is of the order of 210 cm^{-1} .

I take this opportunity to thank Prof. M. N. Saha, F.R.S., for his guidance and interest in this work.

Note added in course of proof reading

There has been a very recent work on SO, by W. W. Watson and A. E. Parker in the *Phys. Rev.*, **37**, pp. 1484-92 (1931). It appears that there is something to be said against the method of

analysis that they have followed. The main point is that they have used the formula

$$\nu = \nu_e + [\alpha'(v' + \frac{1}{2}) + b'(v' + \frac{1}{2})^2] - \alpha''(v'' + \frac{1}{2}) + b''(v'' + \frac{1}{2})^2],$$

the formula for the diatomic molecules, separately for three modes of vibration. If, as they assume, there are three modes of vibration in the molecule it is difficult to follow how the composite formula could be split into three parts as if only one way of vibration existed. The attempt by Victor Henri on 'Formaldehyde' has been made with the help of the composite formula as has been done by me. Moreover, Victor Henri, working with an E₁ spectrograph, has remarked that there are comparatively much fewer bands in this region as has actually been obtained by me. It is difficult to reconcile this fact with the much larger number of bands recorded by Watson and Parker.

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ON THE ABSORPTION SPECTRA OF SATURATED HALIDES

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Communicated by Prof. M. N. Saha.

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The object of the present paper is to report the preliminary work which has been carried out in this laboratory to extend the ideas of Franck¹ regarding the formation of alkali halides to halides of polyvalent elements. A sketch of Franck's ideas has already been given in various papers, and is now so well known that we consider it quite superfluous to give a detailed account of it in this place. Extension of Franck's ideas to polyatomic halides was first made by Messrs A. K. Datta and M. N. Saha,² in a paper on the absorption spectra of some tetra-atomic halides (CCl_4 , SiCl_4 , TiCl_4 and SnCl_4) and recently by Butkow³ to mercury and cadmium halides. The work of Datta and Saha made it probable that the absorption spectra of saturated halides are always continuous, and the beginning of the long wavelength limit of absorption is approximately given by the relation

$$h\nu = R/n \quad (1)$$

where R is the atomic heat of formation, *i.e.*, heat evolved when the compound is formed out of elements taken in the atomic state. ' R ' can be calculated from the following relation

$$R = Q + L_M + \frac{n}{2} D - L_{MH_n} \quad (2)$$

where Q = heat of formation as obtained from thermochemical measurements.
 L_M = latent heat of vaporisation of the metal.
 D = heat of dissociation of the halogen from its natural state.
 L_{MHL_n} = latent heat of vaporisation of the compound.

The absorption spectra of a large number of substances have been investigated. The values of 'R' calculated according to (2) are given below:—

Table 1.—Thermochemical data for the halides for evaluating the atomic heat of formation.

Compound	L_M	Q	$\frac{n}{2}D$	L_{com}	R/n	R_v
MgCl ₂ ...	47	151	58	...	$128 - \frac{L_{com}}{2}$	102
MgBr ₂ ...		130.7	55	...	...	95
AlCl ₃ ...	62	161	87.7	35	92	106
AlBr ₃ ...		123	82.5	37	80	92
Al I ₃ ...		86	73.5	13	73	82
SiCl ₄ ...	42(?)	143	116	6.93	$250 + \frac{L_{Si}}{4}$	114.5
SiBr ₄ ...		106	108	...	...	107.5
SiI ₄ ...		58	99	...	...	80

EXPERIMENTAL PROCEDURE

If we take the series NaCl, MgCl₂, AlCl₃, and SiCl₄, we find that the tendency to vaporise increases with the valency.

NaCl melts at 800°C , and a temperature of 1000°C is required to produce sufficient vapour. MgCl_2 melts at 500°C , AlCl_3 at 260°C , and SiCl_4 is ordinarily a liquid. Hence different kinds of absorption vessels were used for producing the vapour. For temperatures exceeding 600°C , the vacuum graphite furnace was used. For temperatures below 600°C we used a pyrex glass furnace of the design shown in the diagram (Fig. 1) below.

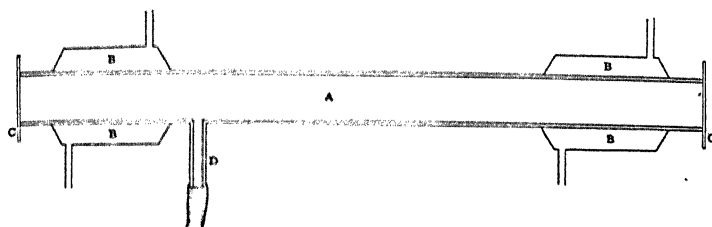


Fig. 1.

A is a pyrex glass tube of about 1 inch in diameter. Two water jackets (Bs in the fig.) are sealed to the tube about an inch from each end for preventing the hot vapour from coming from the inside of the furnace and getting deposited on the quartz windows Cs. D is a piece of glass tube of small diameter attached to the furnace; this is used for inserting the salt and evacuating the furnace whenever necessary. The furnace was heated electrically by winding manganin wire around it and passing high electric current. Knowing the current and the diameter of the wire the approximate temperature of the furnace was estimated.

All these salts were highly hygroscopic and decompose even if they are exposed to air. Only the salts those were obtained in pure anhydrous state were SiCl_4 and AlCl_3 . These were prepared in the laboratory according to the formulae given in standard treatises, specially Mellor's "Comprehensive Treatise on Inorganic and Physical Chemistry." We prepared all the salts in vacuum and designed apparatus to suit the circumstances. After preparation they were distilled a number of

times in vacuum to render them pure. We first started our experiments with magnesium halides.

We used our vacuum graphite furnace for these salts since their temperature of melting was rather high. Underwater spark through two copper electrodes were used all along our experiments for the continuous background. The light from the spark was focussed through the vacuum chamber on the slit of an E_3 quartz spectrograph as shown in the figure (Fig. 2)

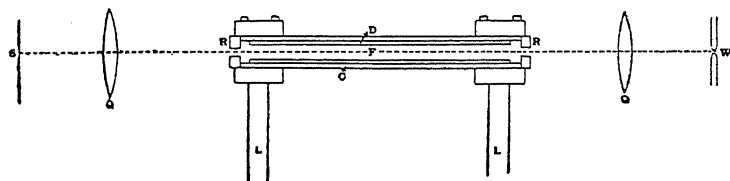


Fig. 2.—F-furnace, Q-quartz lenses, W-water spark between copper electrodes
C-carbon tube, D-silica tube, R-iron rings at the orifice of the furnace
S-slit of the E_3 spectrograph.

with two quartz short focus lenses. The source was so strong that we could photograph the entire length of the continuous spectrum on a Schumann plate in less than half a minute. For obtaining the absorption spectra of aluminium halides we used the furnace used in Fig. 1. For silicon halides we prepared another furnace of a design which is slightly different from what is given in the figure; here, as the salt was in liquid form and the vapour pressure was rather high, it was kept in a bulb attached to the furnace by means of a tubing provided with a stop-cock. The tube was at first evacuated completely of air and moisture, then the stop-cock was opened, and the furnace was filled with vapour to a pressure of about 170 mm. The absorption was found to be continuous and the results are noted in the following table (Table 2).

Table 2.—Results of experiment on absorption.

Compound	Beginning of absorption		Complete absorption λ
	λ	k. cal	
MgCl ₂	2800	102	2500
MgBr ₂	3000	95.4	2500
AlCl ₃	2700	106	2300
AlBr ₃	3100	92	2700
Al I ₃	3500	82	3000
SiCl ₄	2500	114.5	2450
SiBr ₄	2660	107.5	2490
SiI ₄	3550	80.0	3100

The intensity of absorption and the limit of absorption were determined by taking microphotograms of the plate in the Zeiss micro-spectrophotometer of the Physics Department, Patna University. I wish in this place to record our heartfelt thanks to Prof. A. T. Mukerji for having kindly allowed me to use the apparatus.

DISCUSSION

First turning our attention to magnesium halides, we note that the values of L_{MgH_2} are unknown, hence it is rather difficult to compare the result with Datta and Saha's empirical formula. We have for MgCl₂

$$R = 128 - \frac{1}{2}L_{\text{MgCl}_2}$$

and from Table 2 we see that the absorption begins at λ 2800, corresponding to $R=102$. If we suppose the relation to be correct, we have

$$L_{\text{MgCl}_2} = 52 \text{ kcal}$$

and by similar arguments, we can calculate the latent heat for magnesium bromide. Thus we have

$$L_{\text{MgBr}_2} = 40 \text{ kcal}$$

In the case of aluminium halides, where all the data are known, we find that the value of R/n is in every case less than the value derived from L_m (contrast the figures given in the last column of Table 1). For the silicon halides, the value of L_{Si} is unknown; the value obtained from vapour pressure calculations as given in Landolt and Börnstein's table, viz., 42 kcal being evidently too low. But whatever be the value of L_{Si} , it cannot be so great as to make R/n equivalent to the value of L_m (value obtained from the beginning of absorption).

We thus find that the generalised Franck relation

$$L_m \text{ corresponding to } R/n$$

holds strictly for alkali halides only. As we take MgCl_2 , AlCl_3 , and SiCl_4 ... there is probably progressive departure from the relation. Thus the halides approach in their behaviour to HCl , for which $R=105$, whereas L_m corresponds to 2350 A. U., i.e., 122 kcal.

Franck has recently summarised his position in an address published in the 'Naturwissenschaft'.* He finds that

(1) For the alkali halides the agreement is quite fair. This has been extended by Mr. M. S. Desai⁵ to the lithium halides.

(2) For the hydrogen halides,⁶ there is a definite failure.

(3) Silver halides⁷ give rather perplexing results. They give a banded spectrum over which a continuous spectrum is superposed. All explanations regarding the origin of the band spectrum has hitherto been unsuccessful. We have found in this laboratory that the vapours of the chlorides and bromides

of Ca, Sr and Ba, which may be classed in the same group as the silver halides on account of the existence of a metastable d-level, also give band spectra superposed by continuous absorption. This is reported in another paper.

It appears however on theoretical grounds that Franck's formula represents only a limiting case. Franck gave the potential curve for the two states of alkali halides as given in

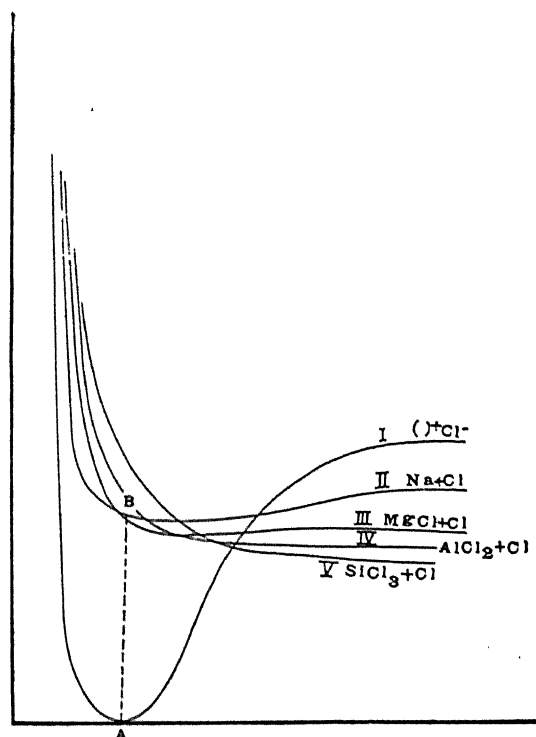


Fig. 3.—Probable potential energy curves for saturated halides.

diagram 3 (curves I and II). It shows at once that the transition from the normal position of the state I (point A in the fig.) to the state II_g results in the dissociation of the molecule. The energy required for this transition is not very much different from that of dissociation of the molecule on account

of the fact that the curve II is more or less horizontal all along after B. Now if we take for poly-atomic saturated molecules a curve slightly different from II (following Herzberg,⁸ who took this particular shape for CH_3I) and represent it by something similar to III we find that, as the positions of the points B_{III} , B_{IV} , B_{V} (not shown in the fig.) are always higher than any point after it along the curve and particularly after the curve becomes horizontal, the energy required to optically dissociate the molecule is greater than the actual energy required to break the molecule. This will explain the departure from the relation $R/n > L_m$ reported in this paper. Thus the behavior of polyhalides shows an increasing tendency to that of HCl , as poly-halides of greater valency are taken.

In conclusion I wish to express my best thanks to Prof. M. N. Saha, F.R.S., for his guidance and interest in the work. I here also thank Mr. H. B. Mohanty for his help in carrying out the experiments.

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STUDIES ON SUPERSATURATION AND CRYSTALLISATION BY THE DILATION METHOD

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Communicated by Prof. P. S. MacMahon.

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Miers¹ carried out some experiments on the change of refractive index in a cooling solution and observed that the Reference index goes on rising until it attains a maximum and then falls suddenly, thereafter decreasing gradually but less steeply. With the first appearance of crystals there is a slight inflexion in the Reference index curve but at the maximum point there is produced a sudden Crop of crystals often attended with a rise in temperature. From further experiments Miers concludes that for any substance there is a supersolubility curve analogous to its solubility curve, and that in accordance with Ostwald's theoretical deductions a solution before crystallisation passes through first a metastable state and then a labile state.

An attempt was made to study the properties of supersaturated solutions by the conductivity method, which was not successful. Magnetic rotation required more elaborate apparatus than we had at our disposal. The dilatation method was next tried and found encouraging.

Experimental.—The apparatus is simple enough and consists of a 100 cc. round bottomed flask with a side tube which can be fitted on to a capillary tube (100 cm.) fixed on a metre scale. The flask has a long ground glass stopper, the lower end projecting far into the body of the flask. The stopper then becomes the container for a thermometer.

The flask contains the solution saturated at a definite temperature but heated to about ten degrees higher. The

upper part of the neck of the flask, the side tube and the capillary tube contain a non-volatile oil. When the joints are satisfactory and a steady condition has been attained the flask is allowed to cool in an air or water bath. The temperatures and the corresponding positions of the oil meniscus in the capillary are noted.

Results.—A substance like NaCl whose solubility variation with temperature is very small does not show tendency for supersaturation. Ammonium oxalate (Fig. 1), potassium nitrate (Fig. 2) and oxalic acid (Fig. 3) can be easily brought to the supersaturated condition, and their dilatation curves are found to be similar.

The first point of inflexion occurs at the saturation point, which generally corresponds with the first appearance of crystals at the bottom of the flask. The next point comes a few degrees lower, when release of supersaturation takes place. Just before this release there is a sudden fall of temperature, analogous to an adiabatic expansion. A cooling curve with temperature-time coordinates (Fig. 4) confirms this. (The release of supersaturation is of course attended with a rise in temperature).

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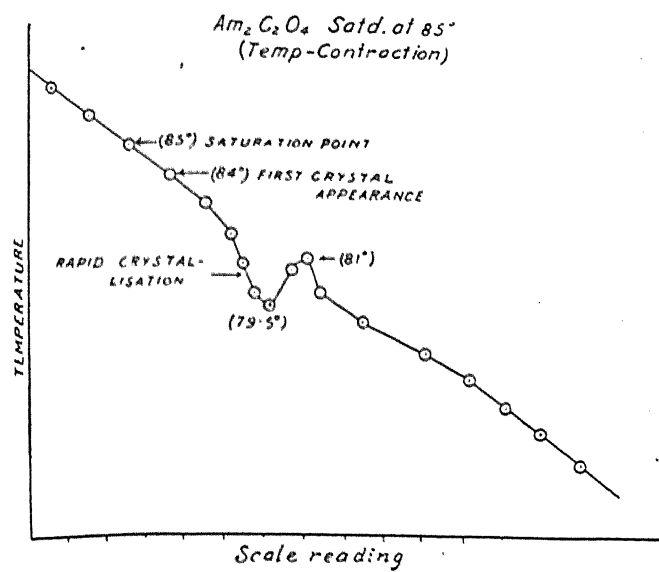


Fig. 1

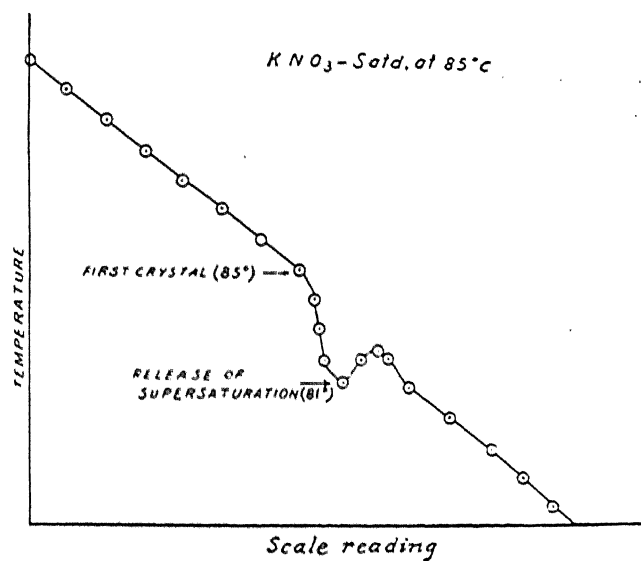


Fig. 2

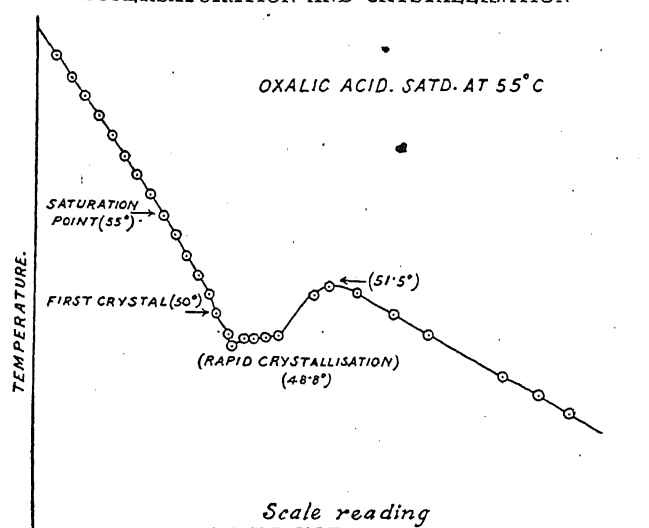


Fig. 3

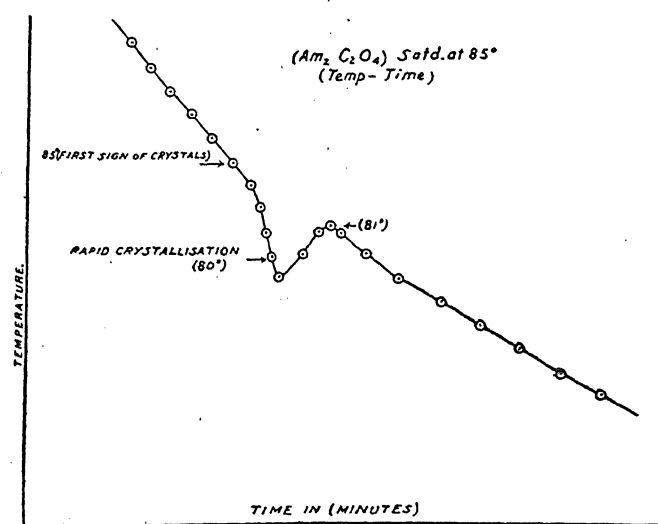


Fig. 4

ON A GENERALIZATION OF A THEOREM OF WIGERT

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Received December 7, 1931.

1. In a recent paper¹ of his, S. Wigert established the following theorem:—

If $f(x) = \sum_0^{\infty} a_n x^n$ is an integral function such that

$$\lim_{n \rightarrow \infty} \frac{n}{\sqrt[n]{|a_n|}} = 0, \text{ and } f(x) \rightarrow 0 \text{ as } x \rightarrow \infty \text{ along the real}$$

positive axis, then the series $\sum_1^{\infty} (-1)^{n-1} f(nx)$ converges for $R(x) > 0$ and represents an integral function of x .

We find that Wigert's theorem is only a particular case of a very general theorem, which it is our main object to establish in this paper. Our theorem is as follows:—

If the Dirichlet's series

$$(1.1) \quad h(s) = h(\sigma + it) = \sum_0^{\infty} a_n e^{-s\lambda_n} \\ (0 < \lambda_1 < \lambda_2 < \dots < \lambda_n \rightarrow \infty)$$

is convergent for $\sigma > 0$, and represents an analytic function of s at the origin;

(1.2) $f(x) = \sum_0^{\infty} c_n x^n / n!$ is an integral function of $x (= \rho e^{i\phi})$ of order 1 and type $k \geq 0$;

(1.3) the series $\sum_1^{\infty} a_n f(\lambda_n x)$ is convergent for at least some real and positive values of x ;

then the function $H(x)$ defined by

$$H(x) = \sum_1^{\infty} a_n f(\lambda_n x)$$

is analytic at least inside the circle $|x| = r/k$, where r is the radius of convergence of Taylor's expansion of $h(s)$ in the neighbourhood of the origin; and further $H(x)$ can have no other singular points than those which are obtained by multiplying the affixes of the singular points of $h(s)$ by those of $\psi(-s)$,

where $\psi(s) = \sum_0^{\infty} c_\nu s^\nu$.

2. Let $h(s)$ and $f(x)$ be as defined in (1.1) and (1.2). Now let us consider the series

$$(2.1) \quad H(s, x) = \sum_1^{\infty} a_n f(\lambda_n x) e^{-\lambda_n s}.$$

Suppose in the first place that $|x| \leq \delta/(k+\epsilon)$, where $0 < \delta \leq (r/2) - \eta$ (η is a small positive quantity to be chosen later on); then $f(x) = O(e^{\delta|x|})$.

By a theorem due to Cramér² the series (2.1) is uniformly convergent in the half plane $\sigma \geq \delta + \epsilon_1 > \delta$; therefore, $H(s, x)$ is an analytic function of s in the half plane $\sigma \geq \delta + \epsilon_1 > \delta$ and of x in the region $|x| \leq \delta/(k+\epsilon)$.

Now, for $\sigma \geq \delta + \epsilon_1$, we have

$$\begin{aligned} H(s, x) &= \sum_1^{\infty} a_n f(\lambda_n x) e^{-\lambda_n s} \\ &= \sum_{n=1}^{\infty} a_n e^{-\lambda_n s} \sum_{\nu=0}^{\infty} c_\nu x^\nu \lambda_n^\nu / \nu! \\ &= (1/2\pi i) \sum_1^{\infty} a_n e^{-\lambda_n s} \sum_0^{\infty} c_\nu \int_C (e^{u\lambda_n x} / u^\nu + 1) du \\ &= 1/2\pi i \int_C g(u) \sum_1^{\infty} a_n e^{-\lambda_n (s-ux)} du, \\ &= 1/2\pi i \int_0^\infty g(u) h(s-ux) du \end{aligned}$$

since the series for $g(u) \left(= \sum_0^{\infty} c_v/u^{v+1} \right)$ and $h(s-ux)$ are uniformly convergent on the path of integration C , which is the circle $|u| = \kappa + \epsilon_2$, if ϵ_2 is suitably chosen, namely $\epsilon_2 < \epsilon_1(\kappa + \epsilon)/\delta + \epsilon$.

Now we wish to show that $H(s, x)$ is an analytic function of s in the neighbourhood of the origin $s=0$.

$h(s-ux)$ is analytic at least inside the circle $|s-ux| = r$; hence for $|x| \leq \delta/(\kappa + \epsilon)$ and $|s-ux| < r$, $h(s-ux)$ is analytic function of x and s .

The inequality $|s-ux| < r$ is obviously satisfied if $|s| + |ux| < r$

or if $|s| < r - (\kappa + \epsilon_2) \delta/(\kappa + \epsilon)$ [$|u| = \kappa + \epsilon_2$]

which will be true if $|s| \leq r/2 + \xi$, where ξ is a small positive quantity $= \eta + (\epsilon - \epsilon_2)\delta/(\kappa + \epsilon)$, where η is suitably chosen now, so that η is $> \epsilon_1 - \xi$.

Since this region of s has a part common with the region $\sigma \geq \delta + \epsilon_1$ in which $H(s, x)$ has already been proved to be an analytic function of s , therefore by the principle of analytic continuation $H(s, x)$ is analytic in s in the circle $|s| < r/2 + \xi$. Consequently, $H(s, x)$ is regular at $s=0$, and

$$\begin{aligned} \therefore H(0, x) &= \sum_1^{\infty} a_n f(\lambda_n x) \\ &= 1/2\pi i \int_C g(u) h(-ux) du \end{aligned}$$

provided the condition (1.3) is satisfied.

Let us write $H(x)$ for $H(0, x)$ for convenience. We shall now study $H(x)$ by the equivalent integral.

Let us set $-u=1/t$. Then

$$H(x) = 1/2\pi i \int \left\{ 1/t g(-1/t) \right\} h(x/t) \frac{dt}{t} \quad (2.3)$$

$|t| = 1/(\kappa + \epsilon_2)$

where $\left\{ 1/t g(-1/t) \right\} = \sum_0^{\infty} (-1)^v c_v t^v = \psi(-t)$ whose radius of

convergence is $1/\kappa$. Let the Taylor's expansion of $h(s)$ namely $\sum_{\nu=0}^{\infty} b_{\nu} s^{\nu}$ be valid for $|s| < r$. Then the integral in (2.3) is

Hadamard's integral for the series $\sum_{\nu=0}^{\infty} (-1)^{\nu} c_{\nu} b_{\nu} x^{\nu}$, which has a radius of convergence at least $= r/\kappa$. Hence $H(x)$ is analytic at least inside a circle of radius r/κ , and inside this circle

$$(2.4) \quad H(x) = \sum_{\nu=0}^{\infty} (-1)^{\nu} c_{\nu} b_{\nu} x^{\nu}.$$

From result (2.3) it follows by the wellknown Hadamard's theorem that $H(x)$ has no other singularities than those whose affixes are obtained by multiplying the affix of any singularity of $h(x)$ with that of any singularity of $\psi(-x) = \sum_{\nu=0}^{\infty} (-1)^{\nu} c_{\nu} x^{\nu}$.

Further, all the results as regards the nature and order of singularities in the case of functions represented by the series of Hadamard's type are applicable here as well.

3. In the particular case when $\lambda n = \nu$, in place of the condition (1.3), let us assume that $a_n f(n) \rightarrow 0$ as $n \rightarrow +\infty$. The power series $\sum_{n=0}^{\infty} a_n f(nx) e^{-sn}$ is convergent at any point on the circle $|e^{-s}| = 1$ by Fatou's theorem, since the function represented by the series is regular in the neighbourhood of the origin $s=0$ for values of x such that $|x| \leq \delta/(\kappa + \epsilon)$, and $a_n f(nx) \rightarrow 0$ as $n \rightarrow +\infty$ for any finite positive value of x . Hence, a particular case of the general theorem proved in § 2 is as follows:

(3.1) *If $h(s)$ satisfies the condition of (1.1),*

(3.2) *$f(x)$ is as defined in (1.2),*

(3.3) *and $a_n f(n) \rightarrow 0$ as $n \rightarrow +\infty$;*

then the function $H(x)$ defined by

$$H(x) = \sum_{n=1}^{\infty} a_n f(nx),$$

has the properties that the series on the right is convergent for

$0 < x \leq (r/2\kappa) - a$, where r is the radius of convergence of Taylor's expansion of $h(s)$ in the neighbourhood of $s=0$, and a is a small positive quantity ;

$H(x)$ is analytic at least inside the circle $|x|=r/\kappa$;

$H(x)$ can have no other singular points than those which are obtained by multiplying the affixes of the singular points of $h(s)$ by those of $\psi(-s)$, where $\psi(s) = \sum_{v=0}^{\infty} c_v s^v$.

As a particular case of the above theorem, we have Wigert's theorem. Let a_n be $(-1)^{n-1}$, and $\kappa=0$.

Then $h(s) = \sum_{n=1}^{\infty} e^{\pi i(n-1)} e^{-ns}$ evidently satisfies (3.1).

Hence, the series $\sum_{n=1}^{\infty} (-1)^{n-1} f(nx)$ is convergent for $R(x) > 0$ and $H(x)$, the function represented by it, is an integral function of x . Further, the Taylor's expansion of $h(s)$ round the origin is given by

$$\begin{aligned} h(s) &= \sum_{n=1}^{\infty} e^{\pi i(n-1)} e^{-ns} = 1/(1+e^s) \\ &= \sum_{\mu=0}^{\infty} (-1)^{\mu} (1-2^{\mu+1}) s^{\mu} \zeta(-\mu)/(\mu!) \end{aligned}$$

where $\zeta(-\mu)$ is Riemann's Zeta function. The radius of convergence of the series is $|s| = \pi$.

The expansion (1.2) gives

$$H(x) = \sum_{n=1}^{\infty} (-1)^{n-1} f(nx) = \sum_{v=0}^{\infty} (c_v/r^v!) (1-2^{v+1}) \zeta(-v) x^v.$$

This expansion is valid all over the plane. From it, we readily see that

$H(x) = 0$, if $f(x)$ is an even function.

4. Let $h_1(s) = \sum_{n=1}^{\infty} a_n' e^{-s\lambda_n'}$, the usual Dirichlet's series, satisfy the condition (1.1), and let its Taylor's expansion be $= \sum_{v=0}^{\infty} c_v s^v$, whose radius of convergence is r_1 , again

let $f_1(x) = \sum_0^{\infty} \frac{b_\nu x^\nu}{\nu!}$ be an integral function of order 1 and type

k_1 . Let $h(s)$ and $f(x)$ be as defined in § 2.

Then by virtue of the expansion (2.4), the two series $\sum_1^{\infty} a_n f(\lambda_n x)$ and $\sum_1^{\infty} a_n' f(\lambda_n' x)$ represent the same function, provided the two series are convergent for some values of x .

5. Lastly, we may remark that if the series $\sum_1^{\infty} a_n f(\lambda_n x)$ is entirely divergent, we may define the sum of the series by $\lim_{s \rightarrow 0} \sum_1^{\infty} a_n f(\lambda_n x) e^{-\lambda_n s}$. From the preceding analysis of § 2, we see that this limit exists even when $\sum_1^{\infty} a_n' f(\lambda_n x)$ is entirely divergent.

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ON THE ABSORPTION SPECTRUM OF CALCIUM CHLORIDE VAPOUR

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The spectra of alkaline earth halides have been studied in emission by a large number of workers. The more important amongst them are Buisson, Eder and Valenta, and Olmsted.¹ But for various reasons the absorption spectrum remained practically uninvestigated. Probably on account of their low vapour pressure, such experiments were not successful. Liveing and Dewar report a green band in absorption due to barium chloride vapour when the salt is heated with reducing agents. After Liveing and Dewar's work Walters and Barratt² studied the problem also in absorption. In some of their experiments, they heated the salt with excess of the corresponding metal, and in others they filled up the furnace with halogen vapour and the metal. They observed that the latter process gives the quantity of vapour sufficient for absorption at a considerable low temperature. This is simply due to the fact that when the furnace is filled with some vapour, distillation is slow, and the vapour formed does not disappear too suddenly. Recently Hedfeld³ investigated the bands in more detail using greater dispersion and analysed them more thoroughly. All these workers ascribed the origin of the bands to a diatomic molecule of the type MX where M stands for one atom of alkaline earth metal and X for one atom of halogen.

From an extension of the ideas of Franck on the interpretation of the absorption spectra of alkali halides, Mulliken⁴

remarked that the absorption spectra of polyatomic halides with saturated valencies will be quite similar to the absorption spectra of the alkali halide molecules. According to this view, *the halides of alkaline earths cannot show band absorption*. The observed bands were therefore interpreted as being due to some diatomic molecule of the type MX as pointed out above. But the case of AgCl^5 absorption which gives an inexplicable band spectrum shows that the Frank's ideas in many cases have to be modified and extended.

If we take a review of the absorption spectra of saturated molecules we see that they can be separated under three distinct groups: (1) NaCl type, (2) HCl type, (3) AgCl type. The first two of these types show only a continuous absorption in the ultra-violet, the third has a banded absorption along with a continuous absorption. In type (1), Franck's theory holds, the binding is said to be ionic; in (2) the theory does not hold, and the binding is said to be atomic*; in (3) no theory explains all the facts. While studying the absorption spectra of polyatomic saturated molecules in the light of Franck's ideas and in view of Datta and Saha's⁶ recent work, we were led to the following conclusions:

(1) Those molecules whose metallic constituent possesses one or more metastable levels, will give rise to a band absorption along with a continuous absorption which is common to every molecule.

(2) The molecules, whose metallic constituent possesses no metastable level, give rise to only continuous absorption in the ultraviolet: If it is a diatomic molecule and of the NaCl type, it obeys Franck's law that the beginning of absorption corresponds to the heat of dissociation into constituent neutral atoms.

With a view to testing our point of view as stated in (1) above we started our experiment with calcium chloride.

* It has recently been shown by Mr. A.K. Datta that Franck's conclusions regarding the hydrogen halides are wrong. He has shown that they are exactly like the alkali halides.

The calcium atom has three sets of metastable states, one arising from the electron composition (C) $(4s)^2$, [(C) denoting the inert gas core of the calcium atom] gives rise to 1S_0 ; the other when the electron composition is (C) $(4s)(3d)$... giving rise to 1D_2 and 3D states; and a third (C) $(3d)^2$ giving rise to 1F , 3P , 1D_2 , 3P_1 , 1S_0 . If we apply Herzberg's ideas⁷ regarding the formation of such molecules as Si N or, CN, etc., into this case as well, we see, that when calcium enters into chemical combination, the electrons may be in any of these configurations in the normal state of the molecule, and on excitation may pass to any other metastable state, such as $(4s)^2-(4s)(3d)$ or $(4s)(3d)-(3d)^2$, this process will give rise to band absorption. Walters and Barratt seem to think that if excess of metal be present, we get a temporary CaCl molecule, and the resulting absorption spectrum is due to this. While this may or may not be true (no decisive proof in support of this hypothesis has yet been brought forward), we differ from Mulliken's ideas that compounds like CaCl_2 will always give a continuous absorption. In fact our experiments prove that CaCl_2 vapour give rise to bands due probably to the transition of the electron in calcium to a metastable state.

From Walters and Barratt's papers we find that any excess of the metal or any reducing agent would at once break the triatomic saturated molecule. So we took particular care to have our salt in pure anhydrous state absolutely free from any excess of metal or any reducing agent.

EXPERIMENTAL PROCEDURE

The salts were heated within an airtight iron tube placed inside a Heraeus platinum furnace to a temperature ranging from 900°C to 1300°C . Rapid evaporation was prevented by filling the tube with dry nitrogen. The ends of the tube were water cooled to protect the quartz windows from being coated with a deposit of the distilled salt. Continuous light from a water spark (copper electrodes) was allowed to pass through the tube and the spectrum was taken on a Leiss E_2

spectrograph. It gives the entire spectrum from λ 8000 Å at λ 2000 Å on a plate 22 cm. in length. Copper arc was used as the comparison spectrum.

The continuous spectrum was found to be cut off at a long wavelength limit. But additional bands were obtained at two positions. The heads of the bands as measured are given in table 1 below. It has been found that the bands are formed best at a particular temperature, which is 1200°C in the case of CaCl_2 . By increasing the temperature the width of the individual absorption band increases till they coalesce. At the lower temperature, on the other hand, the bands are imperfectly formed. Some of the bands show the predissociation phenomena.

RESULTS

There are two systems of bands, (1) one set in the long-wavelength side beginning at λ 3916.8 Å, (2) the second set begins at λ 2850 Å and extending up to λ 2736.6 Å.U. (The band heads are shown in table 1.)

Table 1.—List of observed band heads

System A	...	3916.8
		3902.7
		3891.9
		3877.1
		3866.0
		3855.8
System B	...	2850.5
		2834.3
		2816.1
		2803.4
		2790.0
		2775.1
		2761.6
		2749.5
		2736.6

Beyond λ 2640 Å continuous absorption begins, and extends up to λ 2530 Å where absorption is completely cut off. All these bands are distinct from those of Walters and Barratt which were not obtained in our experiment. The distance between the two systems of bands is of the order $\Delta\nu=10,000\text{ cm}^{-1}$ and this is of the same order of magnitude as the distance of the metastable state of Ca^+ from its normal state viz. $(4s^2)^1S_{1/2} - (3d^2)^1D_{3/2}$ 13650 cm^{-1} .

DISCUSSION ON THE RESULTS

In the table which we give below (table 2) L_M denotes the latent heat of evaporation of the metal, Q is the molecular heat of formation in the reaction



the atomic heat of formation R is calculated from the formula

$$R = Q + L_M + D \quad L_{\text{CaHa}_2} \quad \dots \quad (2)$$

where D is the heat of dissociation of the halogen molecule. L_M for calcium has been calculated by Pilling to be 44 k.cal from his vapour pressure experiments. This seems to be an under estimate.

Calcium halide	Q	L_{MHa_2}	L_M	D
CaF_2	288	...	44	76
CaCl_2	192	..	44	58
CaBr_2	163	..	44	55
CaI_2	129	...	44	49

Table 2.—Showing thermochemical values of heats of formation of Ca-halides along with the heats of dissociation of the halogens from their natural states. All the values in the above table are given in kcal.

The beginning of continuous absorption at λ 2530 Å corresponds to 113 k.cal. If following Datta and Saha we take this equal to $R/2$ we obtain from equation (2) above

$$L_{\text{CaCl}_2} = 66 \text{ kcal.} \quad \dots \quad (3)$$

This is not an unlikely value.

This communication is only of a preliminary nature and without a more detailed investigation, it is not possible to explain the results. We investigated the absorption spectra of SrCl_2 , BaCl_2 , CaBr_2 , and SrBr_2 , and have in every case obtained two systems of bands with continuous absorption beyond the limit of the higher frequency bands. It seems therefore to be fairly certain that they arise from similar causes. It is further noticed that the two systems of bands approach nearer in Sr, and intermingle in Ba-compounds.

In conclusion we take this opportunity to express our heartfelt thanks to Prof. M. N. Saha, F.R.S., for his suggesting the problem and for the interest he took all through the course of the work.

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THE ABSORPTION SPECTRA OF SOME ALKALI FLUORIDES AND THE HEAT OF DISSOCIATION OF FLUORINE

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The absorption spectra of the vapours of some alkali fluorides have been experimentally investigated and the results are interpreted to give the Heat of Dissociation of Fluorine.

The heats of dissociation for the other halogens have been determined by thermal methods by Bodenstein and estimated respectively to be 58.9, 45.2 and 35.2 k. cal. In the case of Fluorine owing to its extreme chemical reactivity the thermal methods are not applicable.

I have found out an indirect method of determining the quantity by reversing the arguments of Franck regarding the absorption spectra of the vapours of alkali halides.

Theory.—It is well known that the alkali halide vapours such as MX give a continuous absorption spectrum. The long wavelength beginning of absorption corresponds to the heat of formation.

$$R = M + X - MX \quad \dots \quad (1)$$

R can be expressed in terms of the heat of reaction Q, by the relation

$$R = Q + \frac{1}{2} D_{X_2} + L_M - L_{MX} \quad \dots \quad (2)$$

where

$$Q = [M] + \frac{1}{2} X_2 - [MX]$$

and D_{X_2} = heat of dissociation of X_2

L_M and L_{MX} are the heats of vaporisations of M and MX respectively.

It is found that if ν be the frequency of the beginning of absorption then $h\nu$ corresponds exactly to the value of

$$R = \frac{N h \nu}{J} = \frac{286000}{\lambda} \quad \dots \quad (3)$$

where λ is the wavelength corresponding to the beginning of absorption.

Knowing all other quantities except Dx_2 in the equation (2) we get the Heat of Dissociation.

In the case of Alkali Fluorides MX we have

$$\frac{1}{2} D_{F_2} = R - [Q + L_M - L_{MF}] \quad \dots \quad (4)$$

Experiment.—I took anhydrous fluorides of Lithium, Sodium and Potassium, vaporised them inside the vacuum graphite furnace of this laboratory, at about 900°–1000°C. in an atmosphere of Nitrogen. Light from an under water copper spark was passed through the vapours and the absorption spectra was photographed by Hilger E₃ quartz spectrograph with fairly wide slit. Copper arc was used as comparison spectrum.

Results.—The beginning of absorption came out to be

LiF	...	...	λ 2160	Å U
NaF	...	...	λ 2370	” ”
K F	...	...	λ 2240	” ”

(the absorption limit not being well defined these figures may involve an error of ± 10 Å U)

The other data taken from Landolt and Börnstein's tables is collected in the following tables.

Table 1

Fluoride	Q	L_M	L_{MF}	Boiling Pt. °C
LiF	120	—	55	1676°
NaF	111	26	56	—
KF	109	24	42	1504°

(values of L_M in the 3rd column are not directly taken from the tables but are calculated from the vapour pressure data.)

Calculation.—We have the relation

$$\frac{1}{2} D_{F_2} = R - [Q + L_M - L_{MF}] \quad \dots (4')$$

calculating R from λ_{obs} and substituting other values from the tables we have

Table 2

Fluoride	Beginning of absorption λ	R in k. cals	D_{F_2} in k. cals
LiF	λ 2160	132.4	(L_M is unknown)
NaF	λ 2370	120.0	78
KF	λ 2240	128.0	74

$$D_{F_2} = 76 \pm 2 \text{ k. cals} \quad \dots \quad \dots (I)$$

as the absorption limit is not sharp the uncertainty of ± 2 is within experimental error.

Heat of Evaporation of Lithium.—In the case of Lithium L_M is unknown for want of vapour pressure data. It has been determined in the paper by making use of the value of D_{F_2} (=76 k. cals), we have

$$L_{Li} = \frac{1}{2} D_{F_2} - R + Q + L_{MF} \quad \dots (5)$$

that gives

$$L_{Li} = 29.4 \text{ k. cal per gram atom} \quad \dots (II)$$

Further work is being done on the absorption of halides of Lithium to check the value of L_{Li} thus obtained.

My sincere thanks are due to Prof. M. N. Saha, F. R.S., for his valuable guidance in the work.

Note.—A more complete paper will appear in the Proceedings of the Royal Society of London (April 1932).

ON THE INTERPRETATION OF X-RAY TERM VALUES

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INTRODUCTION

1. The object of the present paper is to offer a rather radically different interpretation of the X-ray term-values than what is at present usually accepted. The present view-point has been summarized by Pauling and Goudsmit in their book on "Structure of Line Spectra, Chap. X." It is well-known that the diagrammatic lines of X-ray spectra show the same structure as alkali-spectra, and this has given rise to the widespread belief that the X-ray term-values and their differences can be calculated in the same way as term-values for hydrogen or the alkalies, after the introduction of suitable screening constants. But it was pointed out by M. N. Saha and B. B. Ray² that the apparent analogy of X-ray spectra to alkali spectra is rather misleading. It is due to the operation of the Pauli Exclusion Principle which says that defect of a single electron from a closed shell gives rise to the same spectroscopic levels as the presence of one single electron outside a closed shell. Thus $2p^5$5 electrons in the L-shell give rise to the spectroscopic level $^2P_{1/2}$, $^2P_{3/2}$, while one p electron also gives rise to the same levels. Since the X-ray spectra are due to the removal of an electron from some level, and the subsequent jumping of an electron from some outer level to this, it follows that the term-values have to be calculated in a widely different way than that usually followed.

CALCULATION OF TERM-VALUES

2. To illustrate the above point of view, let us take the procedure usually adopted for calculating ν_K , ν_{L_1} , $\nu_{L_{2,3}}$ etc.

Now $h\nu_K$ represents the energy required to remove one electron from the K-shell to infinity, hence the theoretical problem before us is to find out the total energy of an electron in the K-shell. This electron moves in the field of force composed of that due to the central charge $+Ze$, the field due to the companion-electron in the K-shell and the field due to the outer electrons. If the field due to the outer electrons could be neglected, we shall have just the helium problem with the central charge equal to $+Ze$. We specially insist that the field due to the companion in the K-shell be treated separately, as this being in the same quantum orbit, produces much greater effect than other electrons. Hence ν_K should correspond to the $'S_0$ term of He. In no case, can it correspond to the $'S_{\frac{1}{2}}$ term of hydrogen, as is usually accepted. But the field due to the outer electrons cannot be neglected, hence the actual problem becomes more complicated than that of helium.

These considerations apply equally well to the calculation of the term-values for L_{11}, L_{21}, L_{22} ; for L_{11} we find that it corresponds to the $'S_0$ term of Be, the central charge being different. The $\nu_{L_{21}}$ term corresponds to the removal of an electron from the $2p'$ shell giving rise to the $'S_0$ state. For $Z=10$, when the $2p''$ shell is completed, this corresponds to the $'S_0$ -term of Neon. Hence L_{21} -values have to be linked to the $'S_0$ -term of Neon.

The difference $\nu_{L_{11}} - \nu_{L_{21}}$, is usually referred to the $\Delta\nu$ -difference for the 3P terms of hydrogen, but according to the present stand-point, this is to be explained on the same basis as to the $(^3P_2 - ^3P_1)$ differences of F, Ne, $^+Mg^{++}$...

These ideas involve a complete re-calculation of the term-values in X-ray spectra on a basis very different from that followed at the present time.

Before embarking on this venture, we want to present a complete survey of the experimental material.

3. The screening constant for the K-level.—Usually ν_K , the value of the absorption limit is represented by the formula

$$\sqrt{\frac{\nu_K}{R}} = \frac{Z - \sigma_K}{1} \quad \dots \quad \dots \quad \dots \quad (i)$$

where σ_K is known as the screening constant for the K-level.

It was at first thought³ that σ_K was nearly constant, viz., 3.4, for all elements, but this impression was due to the fact that data regarding only a few elements were available. In Table 1, we have collected all the available data regarding σ_K and these have been plotted in Fig. 1.

Table 1.—Screening constant for the K-level

Z	σ_K calc.	σ_K obs.	Diff.	Z	σ_K calc.	σ_K obs.	Diff.
2 He*	...	.657	...	25 Mn	3.06	3.05	-.01
3 Li†	...	.85	...	26 Fe	3.12	3.12	0
4 Be	...	1.19	...	27 Co	3.17	3.15	-.02
5 B	...	1.286	...	28 Ni	3.22	3.23	+.01
6 C	1.59	1.43	-.16	29 Cu	3.27	3.28	+.01
7 N	1.69	1.60	-.09	30 Zn	3.31	3.33	+.02
8 O	1.797	1.77	-.027	31 Ga	3.35	3.33	-.02
9 F	1.898	1.894	-.004	32 Ge	3.39	3.41	+.02
10 Ne	2.089	...	...	33 As	3.43	3.436	+.006
11 Na	2.09	2.13	+.04	34 Se	3.46	3.471	+.011
12 Mg	2.18	2.21	+.03	35 Br	3.49	3.495	.005
13 Al	2.270	2.30	+.03	36 Kr	3.52	...	...
14 Si	2.357	2.36	+.003	37 Rb	3.55	3.548	-.007
15 P	2.44	2.44	0.0	38 Sr	3.57	3.561	-.01
16 S	2.52	2.51	-.01	39 Y	3.585	3.56	-.025
17 Cl	2.598	2.58	-.018	40 Zr	3.60	3.59	-.01
18 A	2.673	2.65	-.023	41 Nb	3.62	3.601	-.019
19 K	2.755	2.70	-.055	42 Mo	3.63	3.615	-.015
20 Ca	2.815	2.78	-.035	43	...	...	...
21 Sc	2.815	2.80	-.015	44 Ru	3.64	3.6	-.04
22 Ti	2.88	2.87	-.01	45 Rh	3.64	3.652	+.012
23 V	2.945	2.93	-.015	46 Pd	3.64	3.644	+.004
24 Cr	3.01	3.00	-.01	47 Ag	3.64	3.645	+.005

* Skinner, *Nature*, Feb. 6, 1932.

† Lindh, *Handbuch d. Exp. Physik*, XX, p. 373 (Electron bombardment method).

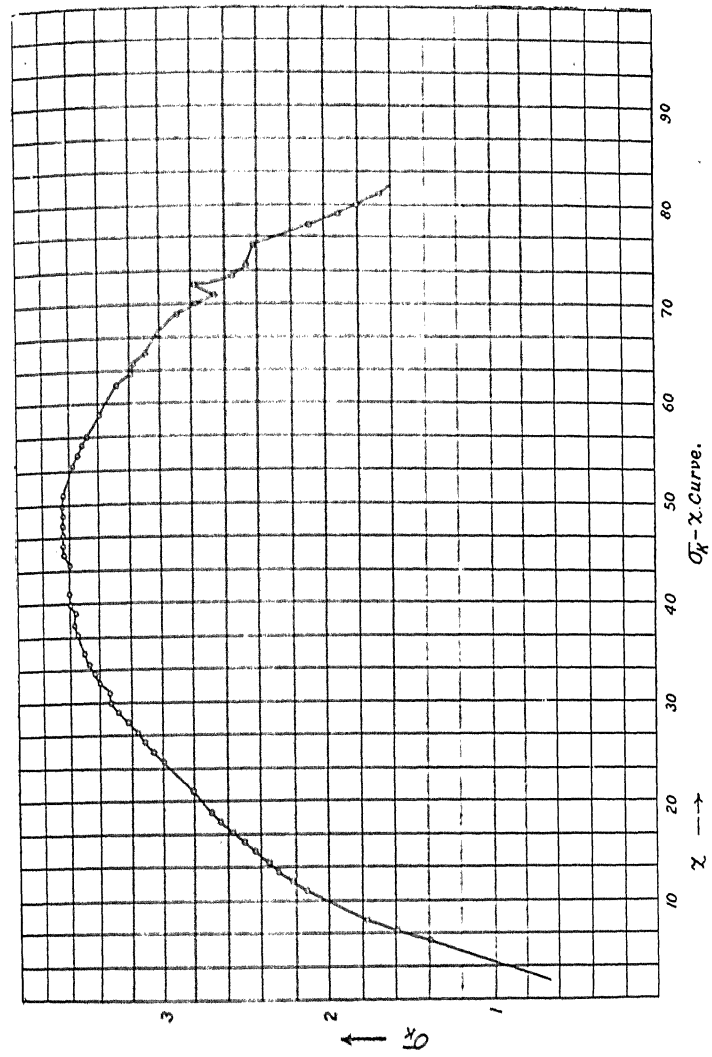


Fig. 1—Showing the relation between σ_K and Z

Z	σ_K Calc.	σ_K obs.	Diff.	Z	σ_K calc.	σ_K obs.	Diff.
48 Cd	3.63	3.642	+0.012	71 Lu	2.72	2.66	-0.06
49 In	3.62	3.644	+0.024	72 Hf	2.64	2.77	+0.13
50 Sn	3.61	3.637	+0.027	73 Ta	2.57	2.55	-0.02
51 Sb	3.60	3.629	+0.029	74 W	2.49	2.46	-0.03
52 Te	3.58	3.616	+0.036	75	2.41	...	...
53 I	3.56	3.602	+0.042	76 Os	2.32	2.42	+0.1
54 Xe	3.53	...	...	77 Ir	...	...	...
55 Cs	3.51	3.535	+0.025	78 Pt	2.14	2.08	-0.06
56 Ba	3.48	3.508	+0.028	79 Au	2.04	1.92	-0.12
57 La	3.45	3.481	+0.031	80 Hg	1.95	1.82	-0.13
58 Ce	3.42	3.452	+0.032	81 Tl	...	1.67	...
59 Pr	3.38	3.39	+0.01	82 Pb	...	1.61	...
60 Nd	3.34	3.413	+0.073	83 Bi	...	1.50	...
61	3.30	...	...	84 Po	...	...	...
62 Sm	3.25	3.28	+0.03	85	...	...	...
63 Eu	3.20	3.18	-0.02	86 Niton	...	...	...
64 Gd	3.15	3.17	+0.02	87	...	...	...
65 Tb	3.097	3.08	-0.017	88 Ra	...	...	...
66 Dy	3.05	3.07	+0.02	89 Ac	...	2.4	...
67 Ho	2.98	3.023	+0.043	90 Th	...	...	...
68	2.92	...	...	91 U ¹	...	...	...
69 Th	2.85	2.89	+0.04	92 Ur	...	-0.07	...
70 Yb	2.78	2.77	-0.01				

The values of ν_K from 92Ur to 12Mg were taken from *Lindh, Handbuch d. Exp. Physik*, Vol. XXIV, p. 196, and σ_K was calculated according to (1). The values of σ_K for elements below Mg are subject to a certain amount of uncertainty, as a regular K_α -line can be obtained only when the L_α -level is complete. In cases where L_α is not completed, K_α -line shows increasing diffuseness. The K-limits have been measured directly by Thibaud⁴ for C, N, O. For the other elements, we have slightly increased the frequency values for the K_α -line which have been observed by a number of investigators.⁵ Helium is the element giving the first K-series, as it has two electrons in the K-shell. Hence ν_K for He corresponds to the ionisation potential of He, viz., 24.5 volts. The curve shows that the σ_K -curve is continuous up to He. This is a proof of the essential correctness of our method of representing the ν_K -limits.

The (σ_K/Z) curve is approximately parabolic, with small kinks at places where a shell becomes complete, and a new shell begins, *e.g.*, at 20 Ca, $\sigma_K = 2.78$ while for 21 Sc, $\sigma_K = 2.80$.

In Sc, the $3d$ -shell is beginning to be formed. The value becomes approximately constant for 37 Rb to 56 Ba [3.54–3.64–3.48] and this gave rise formerly to the belief that σ_K was constant for all elements. But beyond Ba, σ_K rapidly diminishes, and at 92 U, σ_K actually becomes negative, *i.e.*, there is no screening at all.

' σ ' can be roughly represented by the formulae

$$\left. \begin{aligned} \sigma_K &= '895 + '1.74Z - '0011Z^2 \text{ up to } Z=20 \\ \sigma_K &= '895 + '1.21(Z-1) - '0011(Z-1)^2, Z=20 \text{ to } 92 \end{aligned} \right\} \dots (2)$$

The differences between observed and calculated values² are shown in Table 1.

4. Causes of Screening.—According to the ideas developed here, ν_K should be calculated from the equation

$$\nabla_1^2 \psi + \nabla_2^2 \psi + \frac{8\pi^2 m}{h^2} \left[W + \frac{Ze^2}{r_1} + \frac{Ze^2}{r_2} - \frac{e^2}{r_{12}} + V \right] \psi = 0 \dots (3)$$

where ∇_1, ∇_2 correspond to the two K-electrons (3), and r_1, r_2 are their respective distances from the nucleus, W = total energy of the two K-electrons, V is the potential due to the outer electrons and r_{12} the distance between the two electrons. If V were zero, the problem would have reduced to the helium one which has been completely solved by Heisenberg, and numerical formula for the calculation of W has been given by Kellner and Hylleras.³ $W = E_1 + E_2$ = sum of the energies of the two electrons. Hylleras gives the following formulae for the ionisation potential of the electrons in the helium shell:

$$\begin{aligned} \frac{E}{Rh} &= \left[Z^2 - \frac{5}{4} Z + '31488 - '01752 \frac{1}{Z} + \frac{'00548}{Z^2} \right] \\ \frac{E_0}{Rh} &= (Z+1)^2 \quad \dots \quad \dots \quad \dots \quad (4) \end{aligned}$$

The formula (4) is in excellent agreement with experimental data due to Edlen.⁷ This is shown in Table 2 below.

Table 2

	He	Li	Be
I.P. calculated	24.47	75.272	153.140
I.P. observed	24.467	75.219 ± 0.12	153.09 ± 0.10

For finding out the value of ν_K , the value of V must be found. Various methods for determining the value of the potential field in the inside of atoms have lately been developed, and the one due to Fermi⁸ seems to be the most promising. But the mathematical difficulties in the solution have not yet been overcome.

We may, however, compare the values of ν_K as experimentally obtained, with the value of the I. P. of the helium like stripped atoms of the group He to Na. This will give us some idea of the outer screening due to the L-electron shell, as this is being formed by the addition of successive electrons. The comparison is shown in Table 3.

Table 3

Element	I. P. of stripped Atoms	$\frac{\nu}{R}$	σ	$\frac{\nu_K}{R}$	σ_K
2 He ...	24.45	1.81	.655	1.802	.657
3 Li+ ...	75.272	5.56	.642	3.89	1.66
4 B+2 ...	153.09	11.30	.637	7.87	1.195
5 B+3 ...	258.0	19.05	.634	13.80	1.285
6 C+4 ...	390.0	28.81	.632	20.90	1.428
7 N+5 ...				29.3	1.59
8 O+6 ...				38.8	1.77
9 F+7 ...				50.5	1.894
10 Ne+8 ...					2.019

The second column contains the value of the I. P. of the stripped atom, the third shows corresponding ν/R of the stripped atom from which σ in the fourth column has been calculated, taking $\sqrt{\frac{\nu}{R}} = Z - \sigma$; we find that σ varies gradually from '655 to '625. This is in accordance with Hylleras' formula.

In the fifth column, we have values of ν_K/R and the sixth column shows σ_K . It is seen that $\sigma_K > \sigma$ and increases with the number of L-electrons steadily, but on the lower limit $\sigma_K \rightarrow \sigma$ for He. Thus it is apparent that the outer electrons contribute very essentially to the screening, as was first pointed out by Bohr.

5. The ν_{L_1} -values.—The values of the ν_{L_1} -level are given by Lindh¹ up to 37 Rb. For other elements, the absorption limit has not yet been obtained, but we can determine ν_{L_1} from the relation

$$\nu_{L_1} = \nu_{\beta_1} + \nu_K - \nu_{K\beta_1} \quad \dots \quad (5)$$

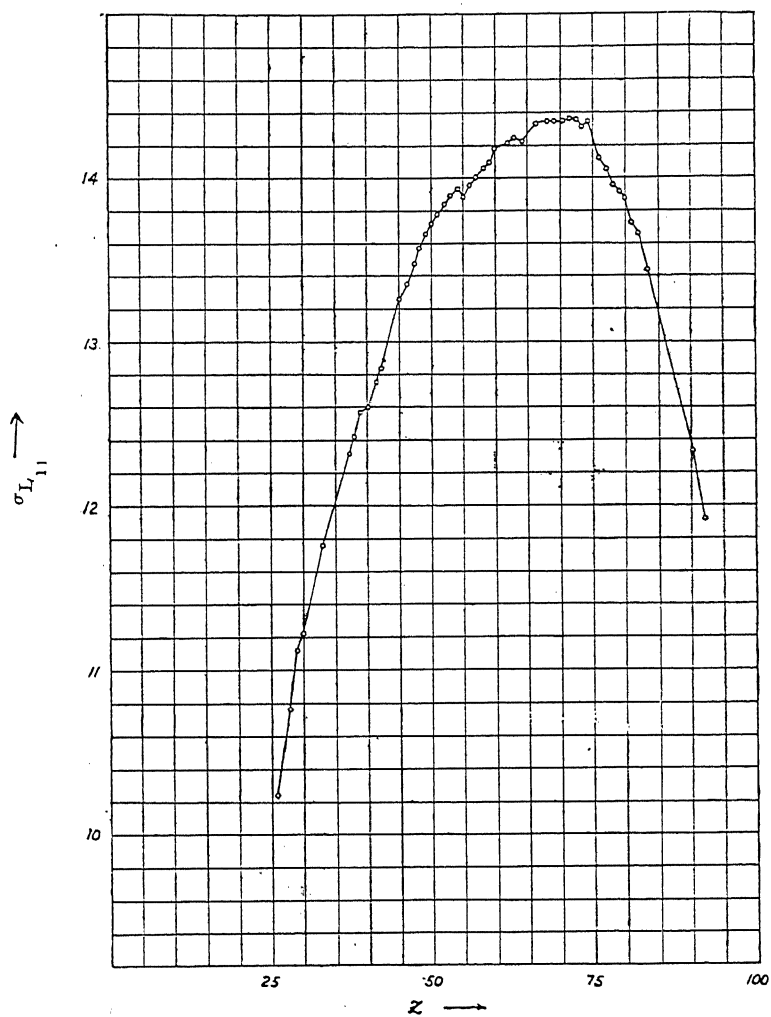
In this way ν_{L_1} has been calculated for 26 Fe, 28 Ni, 29 Cu and 33 As, from Thoreus' measurement of L_{β_1} . The ν_{L_1} and σ_{L_1} values are shown in Table 4, and σ_{L_1} 's are plotted against the atomic number in curve (2). A few other ν_{L_1} -values for elements below 26 Fe may be calculated roughly by a number of indirect methods, *e.g.*, from the empirical relation given by Hertz and Sommerfeld:

$$\sqrt{L_{n1}} - \sqrt{L_{n2}} = \text{const.} = '64 \quad \dots \quad (6)$$

as has been done by Stoner.²

Table 4

Z	$\frac{\nu}{R}$	$\sqrt{\frac{\nu}{R}}$	σ	Remarks
5 B	1'82	1'35	2'30	Electron bombardment method.
6 C	...	1'61	2'78	
		1'71		
8 O	3'69	1'92	4'16	"
9 F	4'67	2'16	4'68	"

$\sigma_{L_{11}} - Z$ CurveFig. 2—Showing the relation between $\sigma_{L_{11}}$ and Z

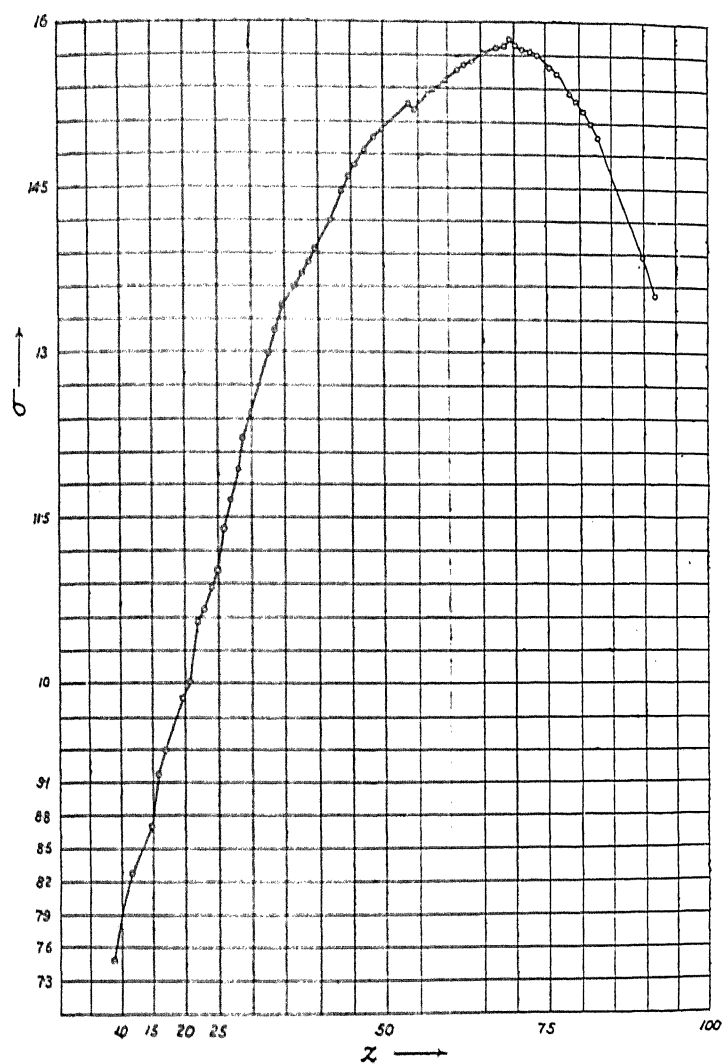
Z	$\frac{\nu}{R}$	$\sqrt{\frac{\nu}{R}}$	$\sigma_{L_{11}}$	Remarks.
13 Al	7.41	2.9	7.20	Lindh
14 Si	10.76	3.28	7.44	...
23 V	43.43	6.59	9.82	...
26 Fe	62.13	7.882	10.24	Thoræus' measurements of L_{β_3}
27 Co	...	...	...	...
28 Ni	71.29	8.62	10.76	...
29 Cu	80.86	8.994	11.112	"
30 Zn	88.19	9.391	11.218	"
31 Ga	...	...	...	...
32 Ge	...	...	...	...
33 As	112.7	10.62	11.76	"
34 Se	...	...	...	...
35 Br	...	...	...	...
36 Kr	...	...	...	...
37 Rb	152.25	12.34	12.32	Lindh
38 Sr	163.57	12.79	12.42	"
39 Y	174.52	13.21	12.58	"
40 Zr	187.60	13.70	12.60	"
41 Nb	199.33	14.12	12.76	"
42 Mo	212.43	14.58	12.84	"
43	...	...	...	"
44 Ru	...	...	...	"
45 Rh	251.83	15.87	13.26	"
46 Pd	266.41	16.32	13.36	"
47 Ag	280.62	16.76	13.48	"
48 Cd	296.13	17.21	13.58	"
49 In	312.14	17.67	13.66	"
50 Sn	329.03	18.14	13.72	"
51 Sb	346.3	18.61	13.78	...
52 Te	363.9	19.08	13.84	...
53 I	382.3	19.55	13.90	...
54 Xe	401.02	20.03	13.94	...
55 Cs	422.5	20.56	13.88	...
56 Ba	441.7	21.02	13.96	...
57 La	462.3	21.50	14.00	...
58 Ce	482.9	21.97	14.06	...
59 Pr	504.0	22.45	14.10	...
60 Nd	524.9	22.91	14.18	...
62 Sm	571.2	23.90	14.2	...
63 Eu	591.3	24.38	14.24	...
64 Gd	619.9	24.89	14.22	...
65	...	...	...	...
66 Dy	667.68	25.84	14.32	...
67 Ho	...	...	...	...

Z	$\frac{\nu}{R}$	$\sqrt{\frac{\nu_{L_{11}}}{R}}$	L_{11}	Remarks
68 Er	719.78	26.83	14.34	
69 Tu	747.19	27.33	14.34	
70 Yb	774.55	27.83	14.34	
71 Lu	802.05	28.32	14.36	
72 Hf	830.70	28.82	14.36	
73 Ta	861.3	29.35	14.3	
74 W	889.9	29.83	14.34	
75	...	...	...
76 Os	957.7	30.94	14.12	
77 Ir	991.0	31.47	14.06	
78 Pt	1022	32.02	13.96	
79 Au	1058	32.54	13.92	
80 Hg	1093	33.06	13.88	
81 Tl	1131	33.64	13.72	
82 Pb	1168	34.17	13.66	
83 Bi	1205	34.78	13.44	
84 Po	...	...	...
85	...	...	...
86 Niton	...	...	...
87	...	...	...
88 Ra	...	...	...
89	...	...	...
90 Th	1508	38.83	12.34	
91 U _{r1}	...	...	...
92 Ur	1603	40.04	11.92	

But there is no certainty that the relation⁶ holds for elements below Fe. We can also try to identify $\nu_{L_{11}}$ with some of the critical potentials found by the electron bombardment method. But these values are also uncertain.

Anyhow the values of L_{11} below Fe are only provisionally given.

The problem of determining $\nu_{L_{11}}$ may be started from that of Beryllium like atoms. We have therefore added in Table 5 the experimentally determined values of the I.P. of atoms stripped to the Be-shell, *viz.*, of Be, B⁺, C²⁺. The corresponding screening constants are shown in column 4. It is found that $\sigma_{L_{11}}$ -values tend to the limit 2.34 for N³⁺. It is found that the

$\sigma_{I_{21}}$ —CurveFig. 3—Showing the relation between $\sigma_{I_{21}}$ and Z

I.P. of atoms stripped to the Be-core can be represented by the formula

Table 5

Element.	I. P. of Stripped atom.	$\frac{\nu}{R}$	σ	σ_{L_1}
Be	9.49	.701	2.320	...
B+	24.19	1.39	2.326	2.78
C++	45.40	3.359	2.334	...
N+3	73.46	5.425	2.342	4.16
O+4	*[109.26]	8.07	2.342	...

* Approximate.

$$E = (Z - 2.34)^2 + .427 - \frac{2.61}{(Z - 2.34)} + \frac{3.25}{(Z - 2.34)^2} \quad \dots (7)$$

6. The $\sigma_{L_{2,1}}$ -absorption levels. — The $L_{2,1}$ and $L_{2,2}$ absorption levels are given by Lindh up to 12 Mg. The values of $\sigma_{L_{2,1}}$ calculated according to the formula $\sqrt{\frac{\nu_{L_{2,1}}}{R}} = \frac{Z - \sigma_{L_{2,1}}}{2}$ are shown in column 4 of table σ , and the variation of $\sigma_{L_{2,1}}$ values with the atomic number is shown in curve (3).

Table 6

Z	$\frac{\nu}{R}$	$\sqrt{\frac{\nu}{R}}$	σ	Z	$\frac{\nu}{R}$	$\sqrt{\frac{\nu}{R}}$	σ
10 Ne	1.59	1.26	7.48	25 Mn	48.2	6.94	11.12
12 Mg	3.50	1.87	8.26	26 Fe	53.42	7.31	11.38
13 Al	5.20	2.28	8.44	27 Co	59.00	7.68	11.64
15 P	9.92	3.15	8.70	28 Ni	64.10	8.04	11.92
16 S	11.68	3.42	9.16	29 Cu	70.4	8.39	12.22
17 Cl	14.81	3.85	9.38	30 Zn	77.1	8.78	12.44
19 K	21.43	4.63	9.74	33 As	101.00	10.01	12.98
20 Ca	25.42	5.09	9.82	34 Se	108	10.41	13.18
21 Sc	30.35	5.51	9.98	35 Br	117.1	10.85	13.4
22 Ti	32.6	5.71	10.58	37 Rb	137	11.71	13.58
23 V	38.3	6.18	10.64	38 Sr	147.88	12.16	13.68
24 Cr	43.3	6.57	10.86	39 Y	158.84	12.60	13.80

Z	$\frac{P}{R}$	$\sqrt{\frac{P}{R}}$	σ	Z	$\frac{P}{R}$	$\sqrt{\frac{P}{R}}$	σ
40 Zr	16983	13.03	13.94	69	70923	26.63	15.74
42 Mo	19339	13.91	14.18	70 Yb	73370	27.09	15.82
44 Ru	21857	14.78	14.44	71 Lu	76287	27.62	15.76
45 Rh	23164	15.22	14.56	72 Hf	79137	28.13	15.74
46 Pd	24528	15.66	14.68	73 Ta	8196	28.63	15.74
47 Ag	25987	16.09	14.82	74 W	84959	29.15	15.70
48 Cd	27455	16.57	14.86	76 Os	9126	30.21	15.58
49 In	29026	17.04	14.92	77 Ir	9413	30.73	15.54
50 Sn	30659	17.51	14.98	78 Pt	9776	31.27	15.46
51 Sb	3229	17.97	15.06	79 Au	10113	31.83	15.34
52 Te	3404	18.44	15.12	80 Hg	10474	32.36	15.28
53 I	35777	18.91	15.18	81 Tl	10829	32.91	15.18
54 Xe	37574	19.38	15.24	82 Pb	11205	33.47	15.06
55 Cs	3964	19.91	15.18	83 Bi	11575	34.02	14.96
56 Ba	41467	20.36	15.28	84	...	...	...
57 La	4344	20.84	15.32	85	...	...	...
58 Ce	45444	21.32	15.36	86	...	...	...
59 Pr	47468	21.79	15.42	87	...	...	...
60 Nd	49590	22.27	15.46	88	...	...	...
62 Sm	5389	23.21	15.58	89	...	...	...
63 Eu	5615	23.70	15.6	90 Th	14497	38.07	13.86
64 Gd	58466	24.18	15.64	91	...	...	...
66 Dy	63222	25.14	15.72	92 Mr	15398	39.24	13.52
68 Er	68262	26.13	15.74				

The starting point for the calculation of the $\sigma_{L_{n-1}}$ -values should be the Neon-atom. This has not yet been attempted. In Table 7 we have given the I.P. of atoms ionised to the Ne-like core as far as known, and the calculated values of screening constants are shown in column 4. It is seen at once that $\sigma_{L_{n-1}}$ tends in the limit to σ_L for Ne. The $\sigma_{L_{n-1}}$ -values are roughly represented by the empirical formula

$$\sigma = 7.728 + .277 (Z - 10) - .00231(Z - 10)^2 - .000001(Z - 10)^3 \quad (8)$$

the I.P. of atoms stripped to the Ne-core can be represented by the empirical formula

$$E = (Z - 6.745)^2 + 1.917 - \frac{42.8}{(Z - 6.745)} + \frac{70.165}{(Z - 6.745)^2} \quad \dots \quad (9)$$

Table 7

Element.	I. P. of Stripped atom.	ν/R .	σ	$\frac{\nu}{R}$	$^{\sigma}L_z$.
Ne	21.49	1.59	7.48	1.59	7.48
Na ⁺	46.78	...	7.28	...	...
Mg ⁺⁺	80.91	5.975	7.112	3.5	8.26
Al ⁺³	121.77	8.993	7.018	5.2	8.44
Si ⁺⁴	168.72	12.473	6.940	...	...
P ⁺⁵	221.9	...	...	9.92	8.70

The value of the electron-affinity of fluorine calculated from this formula comes out to be 7.10 volts, which is in agreement with the value got by Mulliken from extrapolation of corresponding values for Cl, Br, I. The formula is similar to Hylleras' formula for He-like stripped atoms, but it has still to be justified on theoretical grounds.

7. The Probable Cause of Negative Screening.—It is seen that in all cases, the screening factor shows a negative term involving Z^2 . This reduces the screening constant ultimately to almost zero in the case of Ur. As far as we are aware, no explanation has yet been given of this negative screening.

A term $-\alpha Z^2$ in the screening factor, is due to a term involving Z^4 in the energy-value of the electron; the power four of Z at once suggests that this factor is due to some polarisation effect, and the only explanation we can give is that the K-electrons produce a polarisation of the nucleus. Further thoughts and actual calculation do not, however, encourage the idea. Firstly, the K-shell is He-like, hence the distribution of charge is spherical, and no polarisation of the nucleus is expected. Secondly, supposing there is a polarisation $=\alpha E$, where E =field produced by the disturbing cause (here the K-electrons), α must be identified with b^3 , b =the radius of the nucleus. But on actually calculating b from the αZ^2 -term, we

find that b is about 6×10^{-11} , i.e., b is about sixty times larger than the radius usually ascribed to the nucleus. The explanation therefore seems to fail, and we are not in a position to offer any alternative suggestion.

8. This paper is rather in the nature of a survey of the existing problems. The problems suggested which may be taken up later are:—

- (1) To calculate a theoretical expression for the Ionisation Potential of atoms stripped to the Be-core.
- (2) To calculate a theoretical expression for the Ionisation Potential of Ne-like atoms.
- (3) To find a theoretical expression for the screening effect of outer electrons in the general case.
- (4) To find an expression for the potential inside the atom.
- (5) To find an expression for the negative squared terms in the screening constant.
- (6) To find an expression for the doublet separations.
- (7) To calculate energy-values for removing two electrons out of the atoms simultaneously.
- (8) To extend the same treatment to the other X-ray levels.

References

- ¹ For example, See Pauling and Goudsmit, *Structure of Line Spectra*, 180.
- ² M. N. Saha, and B. B. Ray, *Phys. Zeits.* 28, 221, 1927.
- ³ See, A. Sommerfeld, *Atombau*, Fourth edition, p. 447. Sommerfeld calculates the screening constant from the doublet separations. The method followed here was originally given by G. Hertz, see Siegbahn, *the Spectroscopy of X-rays*, p. 171.
- ⁴ Thibaud, *Nature*, 121, 321, 1928.
- ⁵ M. Söderman, *Phil. Mag.*, 1, 1931.
- ⁶ E. A. Hylleras, *Zeits. f. Physik*, 54, 737 1929; 65, 209 1931.
- ⁷ B. Edlen, *Zeits. f. Physik*, 59, 674, 1929; Söderman, *Phil. Mag.*, 10, (1930).
- ⁸ Fermi, *Zeits. f. Physik*, 48, p. 72 1928; 49, 550 1928.
- ⁹ A. E. Stoner, *Phil. Mag.*, 2, 97 1926.
- ¹⁰ Lindb, *Handbuch der Experimental Physik*, XXIV, Part 2, 202.

INDIAN GLASS-MAKING SANDS

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There is no collected or authenticated record of the composition, size, and other properties of the sands which are generally used in the manufacture of glass in India. In order to have an accurate record of the various glass sands used, the following investigation was undertaken.

Ten samples of glass sands, as below, were collected through the kindness of various provincial Directors of Industries, and glass factories.

<i>Ref. No.</i>	<i>Place of origin.</i>
1	Panhai (United Provinces)
2	Jaijon (Punjab)
3	" "
4	" "
5	Barhgarh (United Provinces)
6	Delhi
7	Sawai Madhopur (Rajputana)
8	Jubbulpore (Central Provinces)
9	Ennore (Madras)
10	Ennanoor (Madras)

These apparently represent the whole of the available glass-making sands in India. No complete information is available at the moment showing the extent of the deposits, cost at site, the possibility of washing and grading at site, and the like, which are desirable particulars in considering each deposit as a source of material for glass-making. It is hoped, however, to obtain this information and have it available for prospective users at an early date.

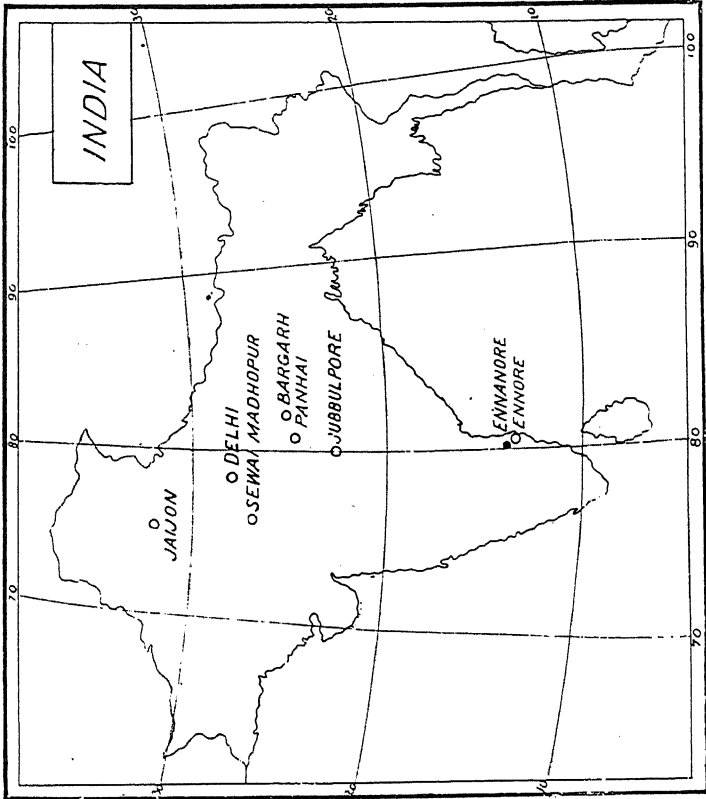
Analysis

All the samples were analysed completely. Silica was estimated directly by continued evaporation with hydrofluoric and sulphuric acids, and the rest, as usual, after fusion with a mixture of potassium and sodium carbonates.

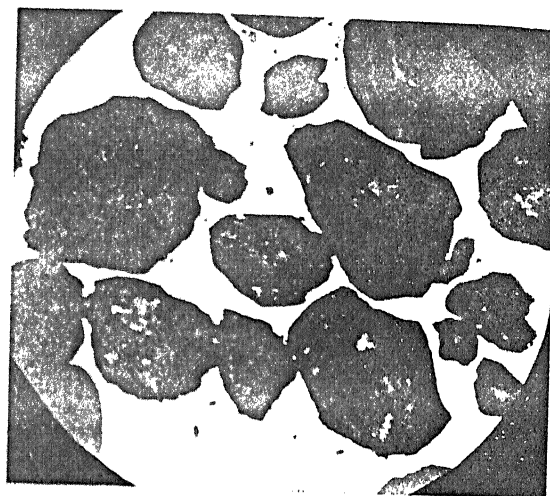
The results are given below :

Number and description	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Loss on ignition	Total
1. Panhai sand	97.51	0.08	0.11	0.05	0.05	0.05	0.20	99.08
2. Jaijon sand No. 1.	99.00	0.14	0.10	0.35	0.05	0.11	0.15	99.90
3. Jaijon sand No. 2.	98.30	0.07	0.25	0.82	0.06	0.17	0.14	99.81
4. Jaijon sand No. 3.	96.54	0.26	0.34	1.60	0.11	0.54	0.40	99.79
5. Barhgarh sand	97.58	...	0.16	1.52	trace	0.18	0.68	100.12
6. Delhi sand ...	97.22	1.40	0.21	0.36	0.15	trace	0.41	99.75
7. Sawai Madhopur sand.	98.44	...	0.33	1.17	0.09	trace	0.43	100.46
8. Jabbulpore sand.	98.04	0.63	0.14	0.91	trace	0.09	...	99.81
9. Ennore sand	97.12	0.22	0.14	0.98	0.10	nil.	0.11	98.67
10. Ennangoor sand.	97.42	0.12	0.24	1.11	0.10	trace	0.24	99.23

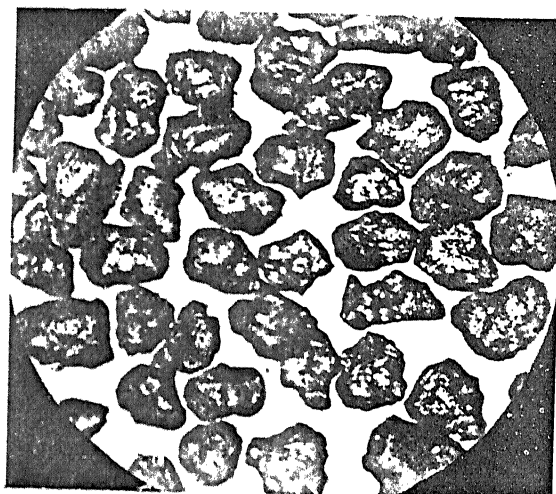
Considering all the figures sample No. 2 (Jaijon Sand No. 1) appears to be the purest sample of sand. Nos. 1, 5, 6, 7 and 8 are approximately of the same order except that No. 6 contains an excessive quantity of Titania and No. 7 an excess of iron oxide. 5, 6 and 7 are the sands usually used for



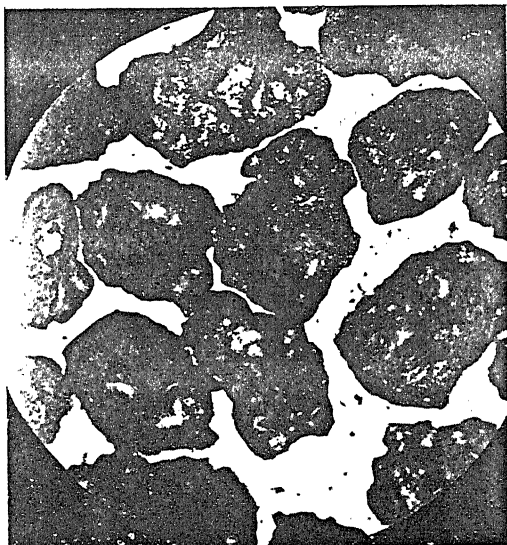
Map showing the position of the sources of the glass-making sand in India.



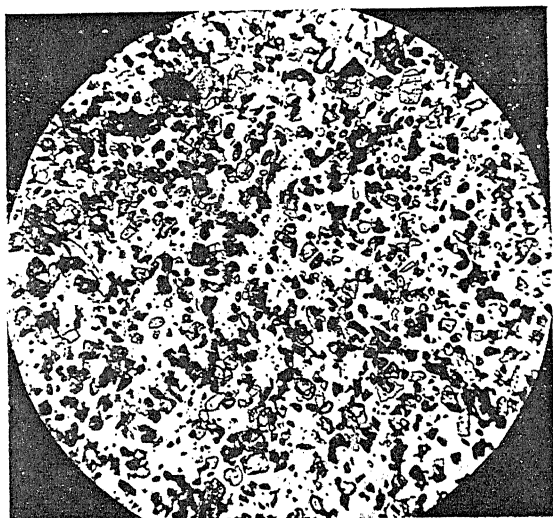
Sample No. 1



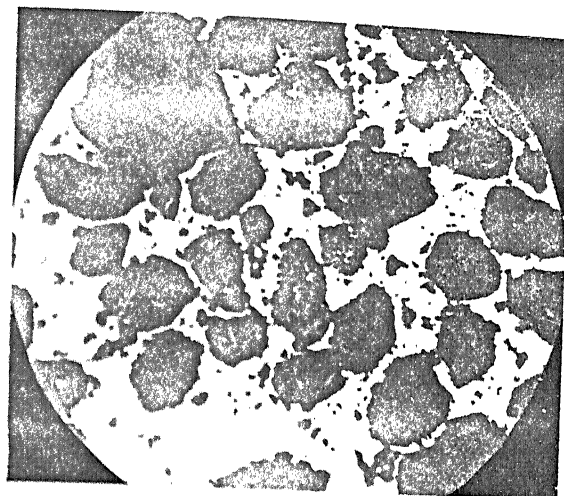
Sample No. 2



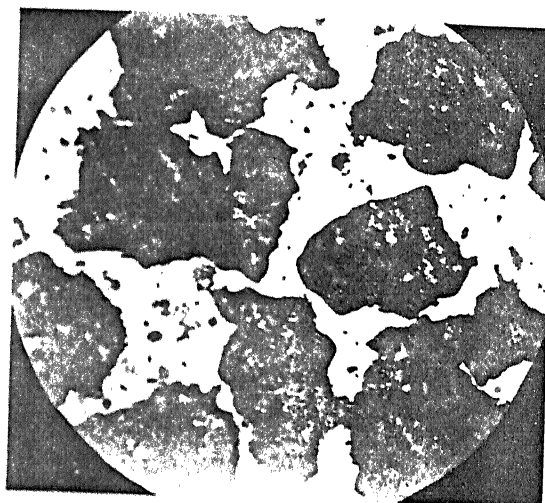
Sample No. 3



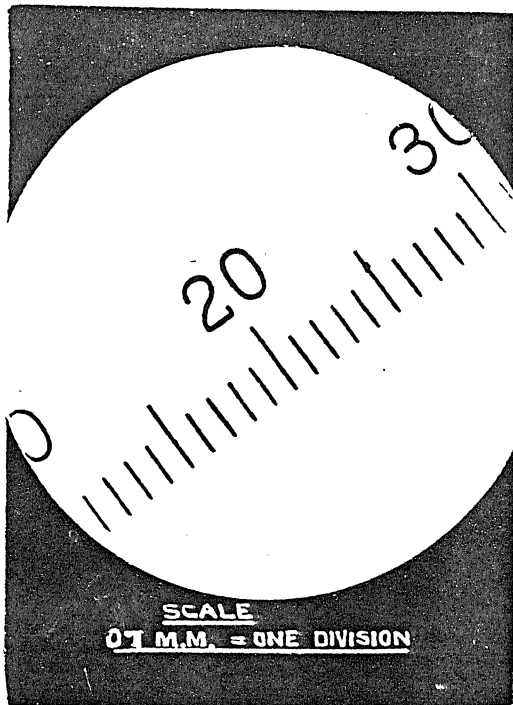
Sample No. 4



Sample No. 5

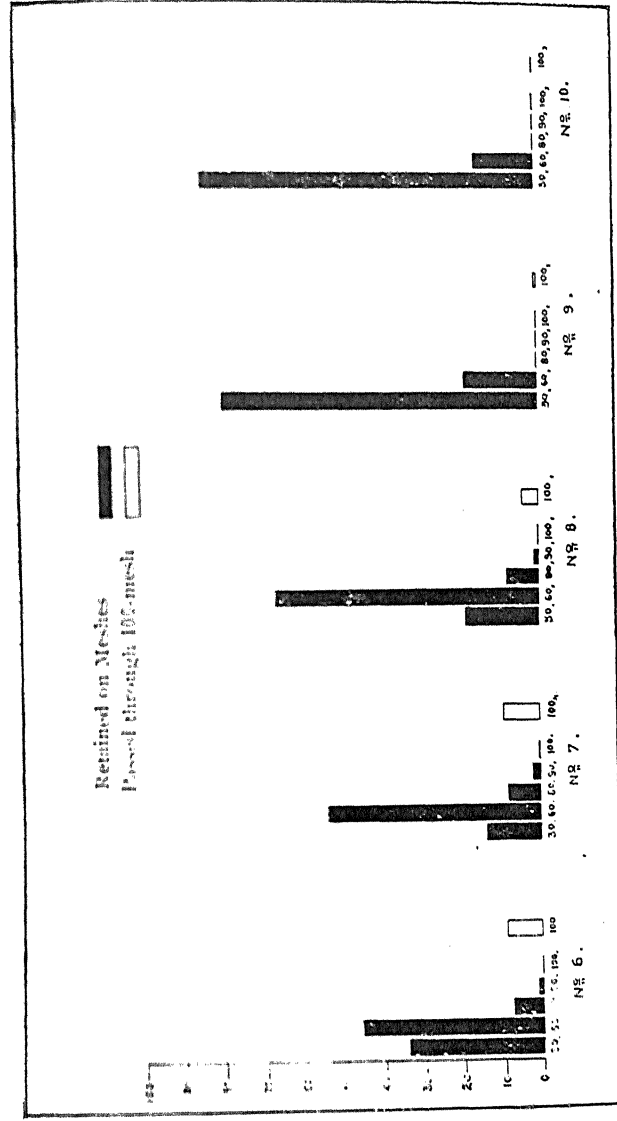


Sample No. 6



No. 11

Scale to judge the size of the particles shown on plates 6, 7, 8, 9, and 10



Diagrammatic representation of percentage of sand successively retained on sieves of different meshes

glass-making in the United Provinces, which is the most important centre for glass manufacture in India.

Grading.

The samples of sand were all successively sieved through I. M. M. sieves of 30, 60, 80, 90 and 100 meshes per inch. One hundred grams of sand were successively sieved and the quantity retained on each sieve was weighed.

Percentage of sand retained successively

Sample No.	30	60	80	90	100 Meshes	Percentage passing through 100 meshes
1	66.3	30.6	1.4	0.4	0.1	1.2
2	0.1	41.5	24.2	3.5	0.6	30.1
3	28.0	43.8	10.4	2.0	0.6	15.2
4	0.2	5.3	10.8	5.5	2.4	75.8
5	11.3	48.5	18.8	2.2	1.2	18.0
6	34.5	46.3	8.3	1.2	0.2	9.5
7	14.4	54.5	8.9	2.5	0.6	19.1
8	18.8	66.2	8.8	1.4	0.4	4.4
9	79.7	18.8	0.9	0.1	0.1	0.4
10	83.7	15.8	0.2	0.1	0.1	0.1

These figures of grading have been expressed in a graphic form in Figures I & II. The actual grain size may be seen from the photographs attached and described below.

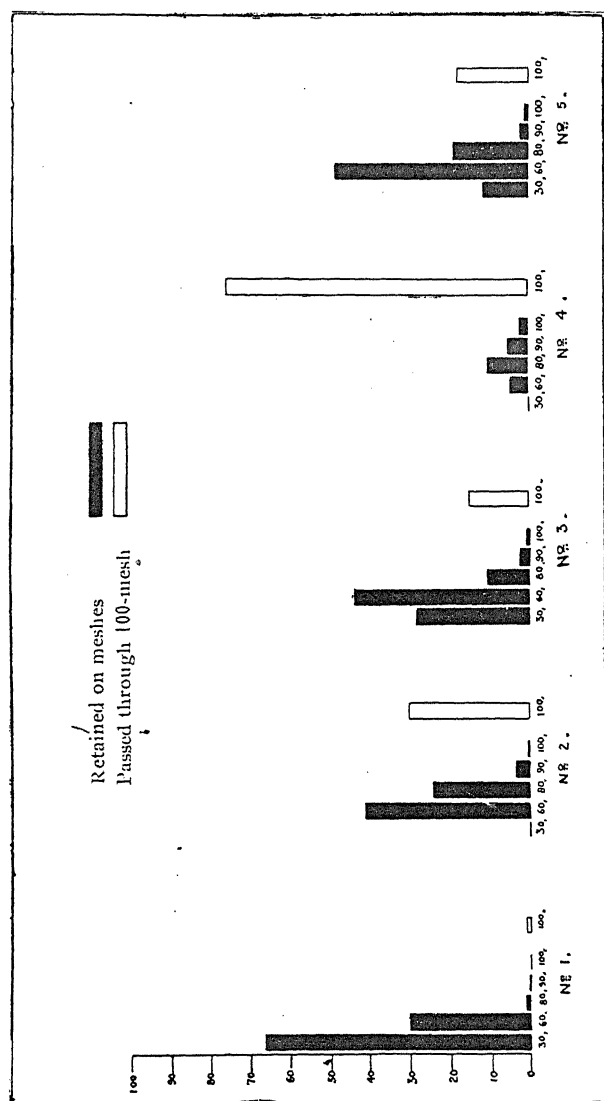
In order to record the size and outline of the particles of sand, the samples were each photographed, as shown in figures of the samples Nos. (Plates 2 : 6) 1—10. The size of the particle can be directly judged from the photograph No. 11 of a scale taken exactly under similar conditions.

Samples Nos. 5, 6 and 7 contain an appreciable quantity of fine particles, Nos. 1 and 3 containing a smaller quantity. Nos. 2, 8, 9 and 10 appear to be the only sands in any way washed or graded before issue. Sample No. 2 appears quite clean and is of uniform size; it is undoubtedly the best glass-making sand amongst those examined. No. 2 approaches the type of Fontainebleau sand, and Nos. 6, 8, 9, 10 are approximately of the same type as the Rhenish deposits of sand used for glass making elsewhere, though all show a high iron and alumina contents.

The various specimens were examined also to determine the quantity of electrolytes present in the sand by the method noted below. The results are recorded, but are not of major importance in judging the sands for glass-making purposes.

Fifteen grams of sand were shaken up with 30 c.c. of conductivity water and the conductivity of the aqueous extract determined in the ordinary way. The electrolyte content of the sand has been calculated from the observed conductivity and is shown as equivalent to the presence of the indicated percentage of Sodium Chloride.

Numbers of samples	% of NaCl on the sand $\times 10^3$
1	1.9
2	0.7
3	0.5
4	1.2
5	0.42
6	0.7
7	0.6
8	7.2
9	0.26
10	0.26



Diagrammatic representation of the percentage of sand successively retained on sieves of different meshes

Sand No. 8 only shows an abnormality. This was a specimen received directly from a glass work and was found on further examination to be contaminated with soda ash dust. In general the figures under electrolyte content give an indication only of the type of water in which the sand has been washed, or from which it has been deposited and then dried. Discussion of their precise value is not of immediate importance for the purposes of this paper.

MATERIALS FOR A MONOGRAPH OF THE INDIAN PETRIFIED PALMS

By B. SAHNI,

BOTANY DEPARTMENT, LUCKNOW UNIVERSITY.

During the past thirteen years the author has brought together from various sources a quantity of silicified material which includes many new species referable to the artificial genus *Palmoxylon*. In the following list the first three species are the only ones previously described; the rest are all new, and are based only on a portion of the material now in hand, so far as it has been critically examined in thin sections. A fuller list, with detailed descriptions and figures, and including also several species represented in the Geological Survey's collections, is in course of preparation.

(N.B.—An asterisk (*) denotes the presence of fibrous bundles between the fibrovascular bundles. The geographical and geological distribution of the known species is indicated in the accompanying map.)

1. *Palmoxylon Blanfordi* Schenk.¹ Schenk (1882, p. 356) gives the locality as the bed of the River Nerbada near Jhansi. This Jhansi is apparently a different place from the famous town of Jhansi near the Betwa River (see Stenzel, 1904, p. 193). Probably washed out of the Intertappean Series (Upper Cretaceous) which is well represented in the area drained by the Nerbada.

*2. *Palmoxylon Liebigianum* Schenk.² Schenk (*loc. cit.*, p. 356) gives the locality as near Sitabalai (meaning Sitabaldi), Province of Nagpur. The age may be presumed, as in the case of *P. Blanfordi*, to be Upper Cretaceous.

3. *Palmoxylon ceylanicum* (Unger).³ From Ceylon; exact locality and age unknown.

4. *Palmoxylon Wadii* Sahni.* From the Upper Siwalik conglomerate of Jammu (Punjab). The conglomerate is regarded as of Pliocene age, but the fossil, being a rolled pebble, may have been derived from older strata.

This species at first seems to resemble *P. Blanfordi*, but of the latter only the central region is known, and a comparison at once shows several points of difference, *e.g.*, the presence of a posterior sclerenchymatous arc, the deeply invaginated anterior sclerenchyma and the presence of numerous scattered thick-walled cells in the ground-tissue.

5. *Palmoxylon jammuense* sp. nov. Source and age as in the above specimen.

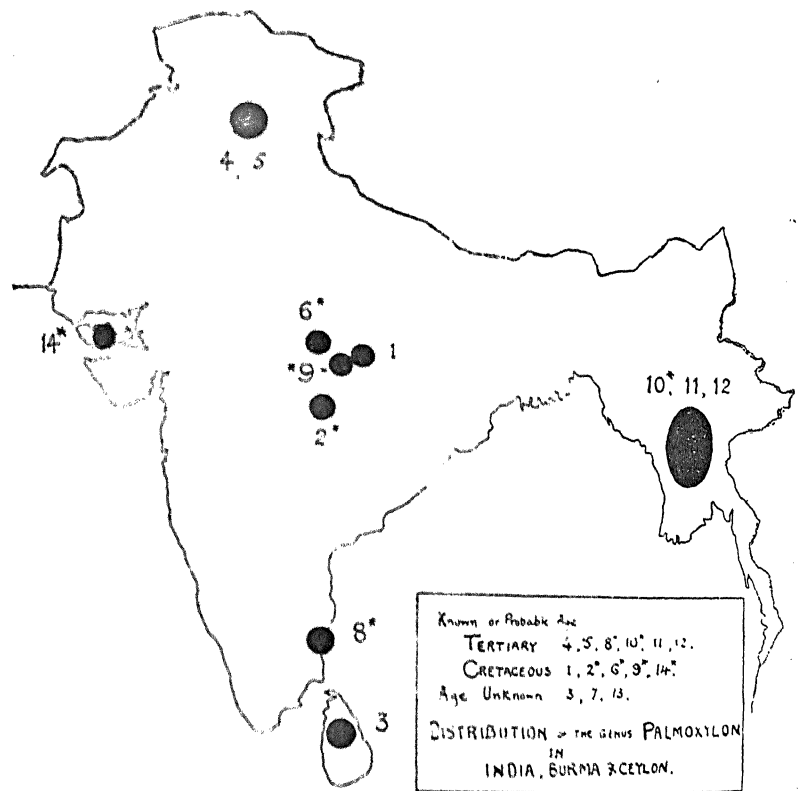
Differs from *P. Wadii* in its much larger bundles, and in the markedly lacunar ground-tissue, with radiate parenchyma only over the vascular part (a point of difference also from *P. Blanfordi* where it surrounds the whole bundle.)

*6. *Palmoxylon sundaram* sp. nov. The species was based upon an exquisitely preserved fragment in the author's collection (locality and age unknown). But an identical structure was found later in several other specimens with the author and in a large tree-trunk (in several pieces) preserved at the Central Museum, Nagpur; this is stated to have been found at Saugor in Central India, and was presumably washed out of the Intertrappean Series (Upper Cretaceous).

A striking feature of this species is the presence, in the central region, of numerous exceedingly minute fibrovascular strands as well as purely fibrous bundles, in addition to the normal fibrovascular bundles. Ground-tissue consisting of small thin-walled cells of a very uniform ellipsoid shape.

7. *Palmoxylon indicum* sp. nov. Type-specimen in the Madras Museum, exact locality and geological age unknown.

There is a great contrast in the size and distribution of the bundles between the outer and inner regions of the stem. If the dermal and central regions were preserved this contrast would be still more marked. The inner bundles are unusually large.



*8. *Palmoxyton pondicherriense* sp. nov. From Pondicherry, age Miocene (?). Type-specimen in the British Museum Geol. Dept. (V. 3339), Harford Collection, 1895.

In contrast to the foregoing species, the bundles in this species decrease in size from without inwards; the sclerenchyma also undergoes a very marked change of form. The purely fibrous bundles possess stegmata as in *P. astrocaryoides* and other species (see Stenzel, *loc. cit.*, p. 146 and Pl. 16, Fig. 186).

*9. *Palmoxyton Edwardsi* sp. nov. Known from two specimens; the smaller one in the British Museum Geol. Dept. (V. 5380), is from near Jubbulpore (Capt. Routh); the larger and better preserved specimen, in the author's collection, is identical in colour and mode of preservation and is taken as the holotype. Both were probably washed out from the Intertrappean Series (Upper Cretaceous).

Distinguished by its unusually small bundles, with the sclerenchyma smaller than the vascular part and presenting to the latter either a flat or slightly concave margin.

*10. *Palmoxyton burmense* sp. nov. From the Tertiary of Burma; collected by Dr. H. L. Chhibber,⁵ late Professor of Geology at Rangoon (Chhibber's No. P. 63).

11. *Palmoxyton compactum* sp. nov. From the Tertiary of Burma; (Dr. Chhibber, No.-P. 365).

12. *Palmoxyton caudatum* sp. nov. From the Tertiary of Burma; Dr. Chhibber, No. P. 432 (type-specimen); No. P. 37, (co-type).

The fibrous part of the bundles shows a narrow and deep invagination from which the vascular part projects in the form of a very long and narrow tail-like process (whence the name *caudatum*).

13. *Palmoxyton Krishna* sp. nov. Exact locality and age unknown; type-specimen in the British Museum Geol. Dept. (V. 7137). The specific name refers to the jet black colour of the specimen.

*14. *Palmoxyton Mathuri* sp. nov. From Lacknipur (? Lakhapur, in Cutch, W. India. Age Cretaceous, and definitely younger than the Umia (Upper Gondwana).

Remarkable for the very small size of its fibrovascular bundles with their characteristic form, the extraordinarily lacunar ground-tissue, which looks like a loose network of cells (recalling a *Hydrodictyon*), and the exceedingly slender fibrous bundles.

For the loan or presentation of material the author wishes to thank Professors D. N. Wadia (formerly of Jammu), A. S. Kalapesi (Bombay), E. J. Blatter (Bombay), H. L. Chhibber (formerly of Rangoon), K. K. Mathur (Benares) and the authorities of the British Museum, the Central Museum at Nagpur and the Madras Museum.

References

¹ Schenk (1882) *Englera* Bot. Jahrb. III, 355; Schenk in Zittel (1890) *Handb. d. Palaeont. II (Palaeophytologie)* p. 886, Fig. 427 (the locality is here given wrongly as Sitabaldi); Stenzel (1904) *Die foss. Palmenholzzer*, pp. 192-193. Pl. VII, Figs. 71-74.

² Schenk (1882) *loc. cit.*, p. 356; Schenk in Zittel (1890), p. 888, Fig. 429; Stenzel (1904), *loc. cit.*, pp. 251-255, Pl. XX, Figs. 244-252 (under *P. ceylanicum* var. *Liebigianum*).

³ Stenzel (1904), *loc. cit.*, Pl. XX, Figs. 242, 243, pp. 250-251, where also the synonymy is given.

⁴ A name first published in 1922; see Sahni (1922), "On some petrified plants from the Mesozoic and Tertiary Rocks of India and Burma," *Proc. Ind. Sci. Congress (Bot. Sec.)*, Madras, p. 123.

⁵ H. L. Chhibber (1927), *Journ. & Proc. Asiat. Soc., Bengal (N. S.)* Vol. XXIII, p. 22.

ON A GENERALIZATION OF THE SECOND THEOREM OF BOURBAKI

BY D. D. KOSAMBI

DEPARTMENT OF MATHEMATICS

The Muslim University, Aligarh

Received April 16, 1932.

In a paper under publication,¹ I have discussed the existence of covariant derivatives, and proved that there are infinitely many parallelisms connected with the paths:

$$\ddot{x}^i + \alpha^i(x, \dot{x}, t) = 0 \quad \dots \quad (1)$$

These parallelisms are defined by

$$D(u)^i = \dot{u}^i + \gamma_k^i u^k + e^i \quad \dots \quad (2)$$

where

$$\dot{x}^k \gamma_k^i(x, \dot{x}, t) + e^i(x, \dot{x}, t) = \alpha^i$$

One of these, for which

$$\gamma_k^i = \frac{1}{2} \alpha_{,k}^i \quad \dots \quad (3)$$

is the fundamental parallelism; with this, a covariant derivative independent of the direction exists only for the symmetric affine connection:

$$\alpha^i = \Gamma_{jr}^i \dot{x}^j \dot{x}^r, \quad \Gamma_{jr}^i = \Gamma_{rj}^i \quad \dots \quad (4)$$

I was not aware that a little-known Russian author, D. Bourbaki, who died of acute lead-poisoning during the Revolution, had anticipated part of these results and pointed out a way to their extension. I shall not go into details here, for an excellent résumé and critique has been published recently by L. Lusternik and L. Schnirelmann.² But it will be clear to geometers acquainted with the last-named paper

that I merely proceed by discarding all three of the 'Iysokohlagodaren' axioms. With our notations, this means that a vector-field $u^i(x)$ will have a covariant derivative $u^i_{|r}$ independent of direction, such that :

$$u^i_{|r} \dot{x}^r = D(u)^i \quad \dots \quad \dots \quad \dots \quad (5)$$

We have, therefore :

$$u^i_{|r} = \frac{\partial u^i}{\partial x^r} + \gamma^i_{kr} u^k + \epsilon^i_r \quad \dots \quad \dots \quad (6)$$

where $\gamma^i_{kr} \dot{x}^r = \gamma^i_k$ and $\epsilon^i_r \dot{x}^r = \epsilon^i$

It follows, with the notation of my first paper, that :

$$\gamma^i_{kr} = \gamma^i_{k;r} \text{ independent of } \dot{x}$$

$$\epsilon^i_r = \epsilon^i_{;r}$$

That is :

$$\alpha^i_{;r} - \dot{x}^r \left[\gamma^i_{kr} + \gamma^i_{rk} \right] = \phi^i_r(x)$$

Thus for the most general α^i , we can have at best:

$$\alpha^i = \gamma^i_{kr} \dot{x}^k \dot{x}^r + \phi^i_r \dot{x}^r \quad \dots \quad \dots \quad (7)$$

For the principal parallelism, $\alpha^i_{;k} = 0$. This gives my former result. For the general γ^i_k , linear in \dot{x} , (7) gives the most general form of the α 's, and hence of the paths.

It will be noted that the $\phi^i_r(x)$ are precisely the ϵ^i_r . Furthermore, an important consequence of this generalization is the inclusion of Cartan's torsion, which is given by:

$$\alpha^i_{kr} = \gamma^i_{kr} - \gamma^i_{rk} = \gamma^i_{k;r} - \gamma^i_{r;k} \quad \dots \quad (8)$$

The second is the most general form of torsion, for all possible parallelisms. The quantities

$$\epsilon^i_r = \alpha^i_{;r} - \left[\gamma^i_{kr} + \gamma^i_{rk} \right] \dot{x}^k$$

are used in the new unitary field theories to denote the electromagnetic components of the forces deforming the hyperspace E_4 .

References

¹ D. D. Kosambi. *Modern Differential Geometries*, to appear in the *Ind. Journ. of Physics*.

² *Topologicheskie Metody v Variatsionnykh Zadachakh*. Math.—mech. Forschungsinstitut, Moskau. 1930, pp. 69–73. I am indebted to Dr. A. Weil for this important reference, and for permission to use his private reprint. I understand that Schnirelmann's work is shortly to be published in German, and this will undoubtedly fill a considerable gap in the existing literature. It is also highly desirable that Bourbaki's posthumous papers, at present lodged with the Leningrad Academy, should be published in full. Unofficial reports claim that Bourbaki was shot after the Mikhail Znak affair with other members of the 'Russko-Angliskii Slovar.'

"SPIN" OF LIGHT*

By SIR C. V. RAMAN, D.Sc., F.R.S., N.L.

The nature of radiant energy had been a long standing problem which had baffled the scientists since the earliest times. So often it was thought that the solution was at hand but as knowledge regarding it grew its nature became more and more obscure. The fight was between two rival theories (1) the Wave theory, (2) the Quantum theory. The position now reached is both curious and interesting. Of the many exponents of the quantum theory namely Planck, Bohr and Einstein, it was Einstein who first gave a clear statement of the idea that for some purposes it was necessary to suppose light to consist of discrete bundles of energy. $h\nu$ was the energy in a quantum of frequency ν . Einstein took the idea of light energy from the wave theory and quantized it. He was also responsible for attributing a pressure to light.

The pressure of light has been securely established and follows as a most logical consequence from the quantum theory. The energy of a light quantum being $h\nu$, $h\nu/c$ was taken as the linear momentum.

The idea of light possessing angular momentum was first clearly conceived by Poynting who said that circularly polarised light should have spin. The angular momentum and spin are not the same. A body moving with a velocity v may be said to have angular momentum about a point fixed in space but real intrinsic spin is different. It must, in order to possess this spin, rotate about a definite axis.

The first demonstration of the Photon having a linear momentum was given by Compton. From the collision of a quantum and a free electron he could show that the quantum possessed the theoretical value $h\nu/c$. The spin of the photon so far had been merely paper idea. There was no definite method by which a definite answer could be given. On the

* Speech delivered by Sir C. V. Raman, D.Sc., F.R.S., N.L., at the first annual meeting of the Academy of Sciences held on 27th of November 1931.

classical theory it can be shown that plain polarised light should not possess angular momentum.

Maxwell by theoretical calculations and Hertz by his experiments, firmly established the idea that light was electromagnetic in nature. We find on Maxwell's theory that light can have angular momentum $+h/2\pi$ and $-h/2\pi$ according as it was right handed circularly polarised or left handed. Intermediary values were also possible but the quantum theory hates all vulgar fractions. To sum up the experiments on light spin carried out in laboratories at Calcutta give the result that light quantum has always got an angular momentum due to spin given by $\pm \frac{h}{2\pi}$ only. It can have no intermediate values nor can

it have 0 or values greater than this unit. Plain polarised light may be taken to consist of photons with 50 per cent having right handed spin and the other 50 per cent having left handed spin. The idea of spin gives it a complete picture. A quantum now has

- (1) Energy
- (2) Momentum
- (3) Spin.

The conception of the spin enables us to link together the frequency, energy, etc. The frequency comes out as a ratio of energy to spin. Polarisation too is completely explained. The wave conception on face becomes superfluous.

The lecturer explained the way in which modified lines were produced in Raman Effect and gave information regarding the state of the molecule. The various cases of Raman Effect were illustrated by photographs of the scattering by Oxygen, CS_2 , CCl_4 , etc. The wings accompanying the lines were explained as due to unresolved rotational effect. In hydrogen on account of its being a light molecule these lines were separated by a larger frequency interval. When measurements regarding the intensity and polarisation of these lines were carried out in the careful experiments of Bhagwantum they revealed a discrepancy of 100 per cent from results calculated on the classical theory.

The depolarisation of the scattered light was examined first without resolving it into a spectrum and then the depolarisation of the modified and unmodified part was measured separately. For making the first observation the slit was opened wide. Interesting results at variance with the classical concepts were obtained.

The difficulty is cleared if we go back to the fundamentals and try to find out why it is that the quantum produces rotational changes in the molecule. The answer is that the quantum itself has a spin and the principle of the conservation of angular momentum is satisfied. Light quantum is like a cloud which has a spin; the molecule becomes entangled and the rotation is changed. From this concept the depolarisation of the scattered light for a simple molecule like that of hydrogen can be calculated. The result obtained by Bhagavantam shows complete agreement. There is now absolutely no doubt that the photon has got a spin, concluded Sir C. V. Raman.

BUSINESS MATTERS

PATRON

His Excellency Sir Malcolm Hailey, G.C.I.E., K.C.S.I., I.C.S.
The Governor of the United Provinces of Agra and Oudh.

HON'Y. FELLOW

The Hon'ble Mr. J. P. Srivastava, M.Sc.,
The Minister of Education,
The United Provinces of Agra and Oudh.

THE INAUGURAL MEETING

The inaugural meeting of the Academy of Sciences was held in the Vizianagram Hall, Muir College Buildings, Allahabad, at 5 p.m. on Tuesday, March 1, 1932. His Excellency Sir Malcolm Hailey, G.C.I.E., K.C.S.I., I.C.S., the Patron of the Academy, presided over the function. Prof. A. C. Banerji, one of the General Secretaries, read the Report of the Academy of Sciences.

Prof. MacMahon, the other General Secretary, read the messages of goodwill received from Prof. Albert Einstein and Lord Rutherford. Prof. M. N. Saha, the President of the Academy, read his Inaugural address. His Excellency Sir Malcolm Hailey then delivered his speech.

Prof. K. N. Bahl, the Vice-President of the Academy, proposed a vote of thanks to His Excellency the Governor, and Principal Drane of Cawnpore seconded the vote of thanks.

REPORT

The Council of the Academy of Sciences of the United Provinces has the honour to submit the following Report on the formation of the Academy and on the state of its affairs during the period beginning from the 1st of January, 1931, till the 29th of February, 1932.

HISTORY AND PROGRESS OF THE ACADEMY

Since the institution of the unitary and teaching Universities in the United Provinces of Agra and Oudh, there has been a general desire on the part of the scientists of these provinces to unite and form themselves into a corporate body for the sake of cultivation and promotion of science in all its branches within the provinces. A strong plea for starting an Academy of Sciences was put forward by Prof. M. N. Saha in an article published in the Allahabad University Magazine of October 1929. Every year quite a large number of scientific papers from workers in the United Provinces are being published in the journals of learned Societies abroad. These foreign Societies are usually accommodating, but owing to enormous increase in the output of scientific work after the War in every country, they find it extremely difficult to cope with the demand in their own countries. Hence workers in India have often to wait for even more than a year to get their papers published in other countries. So the necessity of forming an Academy of Sciences which would hold regular meetings for discussion of papers received from the scientific workers in the United Provinces and would also publish the full papers or their short abstracts, has been very keenly felt.

When the Indian Science Congress met at Allahabad in January 1930, a large number of scientists assembled here from all parts of India. This unique opportunity was availed of, and a meeting of the scientists of these provinces (to which the

scientists from other parts of India were also invited) was held to discuss the question of starting an Academy and defining its functions.

A provisional committee was formed to frame the Constitution and the Rules and Regulations of the Academy, and to approach the Government for a suitable grant for the Academy. Several meetings of this Committee were held and the draft Memorandum and Rules and Regulations were drawn up. In framing the Rules and Regulations and in drawing up the constitution the Committee was guided by those of the Royal Society of London and the Asiatic Society of Bengal. The Committee prayed for an interview with His Excellency the Governor which His Excellency was pleased to grant. A Committee consisting of Profs. M. N. Saha, P. S. MacMahon and K. N. Bahl waited upon His Excellency Malcolm Hailey who was kind enough to discuss in general terms the draft constitution of the Academy and approve of it. His Excellency graciously consented to become the Patron of the Academy and was pleased to recommend a recurring grant of Rupees four thousand (Rs. 4,000) a year for the Academy. But for the active and sympathetic interest taken from the very beginning by His Excellency, the Patron, it would have been impossible to start the Academy and set it going.

The Academy of Sciences was duly registered under Society Registration Act XXI of 1860 on the 4th of December, 1930.

The main objects of the Academy are :

- (a) (i) The cultivation and promotion of science in the following branches—
 - (1) Mathematics,
 - (2) Physics,
 - (3) Chemistry,
 - (4) Zoology,
 - (5) Botany,
 - (6) Mining and Geology,
 - (7) Agriculture,
 - (8) Technology,
 - (9) Medicine,

- (ii) any other branches of science which may be added later on, when desired by the Council and sanctioned by the Ordinary Annual Meeting of the Academy;
- (b) to publish from time to time a bulletin containing abstracts of research work done on the above-mentioned branches of science;
- (c) to publish Transactions and Memoirs contributed by Fellows and Members of the Academy;
- (d) to organize a Science Library for the Provinces;
- (e) to hold meetings and discussions on scientific problems, including those dealing with the welfare of these Provinces;
- (f) to undertake, through properly constituted committees, such scientific work of public importance as it may be called upon to perform;
- (g) to co-operate with other organizations in India and abroad, having similar objects;
- (h) to do and perform all other acts, matters and things that may assist in, conduce to, or be necessary for the fulfilment of the abovementioned aims and objects of the Academy.

It will be found on perusal, that the Rules and Regulations are extremely liberal and democratic, and it is possible for every scientific worker and lover of science to join the Academy. There is provision to elect a certain number out of the Ordinary Members as Fellows on the basis of their eminence in scientific work. The number of Fellows at any time shall not exceed thirty. The rules are not rigid, and if the Members are of opinion that there should be no exclusive distinction like the Fellowship, the rules may be amended accordingly by the Academy.

The Academy's grateful thanks are due to Mr. S. C. Chaudhury, for the help which he had given us regarding

legal points in framing the Constitution, and Rules and Regulations.

Messages of goodwill have been received from many eminent scientists of the world, viz., Prof. Albert Einstein (Germany), Lord Rutherford of Nelson, Sir A. S. Eddington (Cambridge), Prof. R. Gold-Schmidt (Germany), Prof. James Walker (Scotland), Prof. A. Sommerfeld (Germany), Prof. M. Siegbahn (Sweden), Prof. E. S. Goodrich (Oxford), Prof. R. A. Millikan (America), Sir C. V. Raman (Calcutta), Sir P. C. Ray (Calcutta), and Sir J. C. Bose (Calcutta).

The first meeting of the Council of the Academy was held on January 20, 1931, and the first Ordinary Monthly meeting of the Academy was held on the 14th of February, 1931. The Inaugural ceremony could not be held on the occasion of the first meeting of the Academy as His Excellency Sir Malcolm Hailey our Patron was out of India at the time. Later on it was decided to request His Excellency to fix a date for the Inaugural meeting of the Academy.

So far all the meetings of the Academy of Sciences have been held in Allahabad. It is also intended to hold some of the Ordinary Monthly meetings in other places of the United Provinces where there is a sufficient number of members, and a start in this direction was made at Lucknow in December last.

The Academy has 87 Ordinary Members on its roll at present, of whom 19 are Founder-Fellows. Vigorous steps are being taken to increase the number of members. The annual subscription of Resident Ordinary Members is Rs. 15 and that of Non-Resident Ordinary Members residing outside the territorial limits of the United Provinces, is Rs. 10.

The Academy has not yet got a building of its own and is in this respect like its illustrious model, the Royal Society of London, which, though started by a band of enthusiastic workers in 1660, could not be formally accommodated in a house till 1663, owing to the Civil War in England, and was known for some time as "The Invisible College." With the help of the Government and generous public we hope that the period of

"invisibility" of our Academy will be over soon. We realise that as long as the present economic depression lasts it will not be advisable for us to appeal for funds to construct a building for the Academy. But when conditions improve we shall issue an appeal for the building fund and shall also try to raise additional funds by applying to all the Universities of these Provinces for suitable annual grants, and by inviting persons of wealth and high standing who take an interest in science to become benefactors of the Academy by contributing Rs. 1,000 or more to the funds of the Academy.

We are subscribing a large number of journals on different scientific subjects, and we have taken care not to duplicate the journals. These journals are not subscribed by any of the Universities in the United Provinces or by the Allahabad Public Library. So far thirty-seven papers have been read before the Academy, and we have begun to publish a bulletin of the Academy in parts.

The list of 19 Founder-Fellows is given in Appendix A.

ABSTRACTS OF THE PROCEEDINGS

The list of the Office-Bearers and Members of the Council to which the management of the affairs of the Academy was entrusted for the year 1930-31 is given in Appendix B.

Appendix C contains the list of names of 87 Members, who were on the roll of the Academy on the 31st of March, 1932.

It was resolved that such journals as would be useful for the scientific workers excluding those usually subscribed by the Universities of the United Provinces were to be recommended. The names of the Members who were requested by the Council to recommend suitable journals for the Academy are given in Appendix D.

Appendix E contains the names of the Members of the Publication Committees in different subjects.

It was resolved that the President be requested to hold the ordinary meetings of the Academy as far as possible on holidays but not on Sundays, so that it may be convenient for the Christian members as well as for members not residing in the town where a meeting is to be held to attend it.

It was resolved that some of the ordinary monthly meetings of the Academy of Sciences be held at university and educational centres other than Allahabad, where there is a sufficient number of members to form a quorum and where the members are prepared to make arrangements for the meeting.

The following two members were elected Fellows of the Academy in the Fellows' meeting held on the 27th of November, 1931.

1. Dr. H. R. Mehra, Ph.D.
2. Dr. T. Vijayanaghavan, D.Phil.

The following members were elected office-bearers and the Members of the Council for the year 1932 in the annual meeting held on 27th of November, 1931.

President

1. Prof. M. N. Saha, D.Sc., F.R.S., F. Inst. P., F.A.B.S.

Vice-Presidents

2. Prof. N. R. Dhar, D.Sc., F.I.C., I.E.S.
3. Prof. K. N. Bahl, D.Sc., D.Phil.

Hony. Treasurer

4. Prof. D. R. Bhattacharya, M.Sc., Ph.D., D.Sc.

General Secretaries

5. Prof. P. S. MacMahon, B.Sc., M.Sc., F.I.C.
6. Prof. A. C. Banerji, M.A., F.R.A.S., I.E.S.

Foreign Secretary

7. Prof. Ch. Wali-Mohammad, M.A., Ph.D., I.E.S.


Other Members of the Council

8. Prof. K. C. Mehta, Ph.D., M.Sc.
9. Dr. S. S. Nehru, M.A., Ph.D., I.C.S., M.L.C.
10. Prof. H. D. H. Drane, M.Sc., Ph.D., A.M.I.E.E.
11. Prof. K. K. Mathur, B.Sc., A.R.S.M.
12. Dr. Luxmi Narayan, D.Sc.
13. Dr. D. N. Forman, M.D.
14. Prof. B. Sahni, D.Sc., Sc.D., F.L.S., F.A.S.B.
15. Dr. P. L. Srivastava, M.A., D.Phil.
16. Prof. André Weil, D.Sc.

APPENDIX A

LIST OF FOUNDER-FELLOWS (1930-31)

1. Prof. A. C. Banerji, M.Sc. (Cal.), M.A. (Cantab.), F.R.A.S. (Eng.), I.E.S., Professor of Mathematics, Allahabad University, Allahabad.
2. Dr. Luxmi Narayan, D.Sc.(AlI.), Reader in Mathematics, Lucknow University, Lucknow.
3. Prof. André Weil, D.Sc. (Paris), Professor of Mathematics, Muslim University, Aligarh.
4. Prof. M. N. Saha, D.Sc. (Cal.), F.R.S., F.A.S.B., F.Inst.P., P.R. Scholar, Professor of Physics, Allahabad University, Allahabad.
5. Prof. Ch. Wali-Mohammad, M.A. (Cantab.), Ph.D. (Gottingen), I.E.S., Professor of Physics, Lucknow University, Lucknow.
6. G. Chatterjee, Esq., M.Sc., Meteorologist, Upper Air Observatory, Agra.
7. Prof. N. R. Dhar, D.Sc. (Lond.), Docteur ès Science (Paris), F.I.C., I.E.S., Professor of Chemistry, Allahabad University, Allahabad.
8. Prof. P.S. MacMahon, B.Sc. (Hons., Oxon.), M.Sc. (Manchester), Professor of Chemistry, Lucknow University, Lucknow.
9. Prof. D. R. Bhattacharya, M.Sc. (AlI.), Ph.D. (Dublin), Docteur ès Sciences (Paris), Professor of Zoology, Allahabad University, Allahabad.
10. Prof. K. N. Bahl, D.Phil. (Oxon.), D.Sc. (Punjab), Professor of Zoology, Lucknow University, Lucknow.
11. Prof. J. H. Mitter, M.Sc., Ph.D. (Lond.), Professor of Botany, Allahabad University, Allahabad.
12. Prof. B. Sahni, D.Sc. (Lond.), Sc.D. (Cantab.), F.L.S., F.A.S.B., Professor of Botany, Lucknow University, Lucknow.
13. Prof. K. C. Mehta, Ph.D. (Cantab.), M.Sc. (Punjab), Professor of Botany, Agra College, Agra.

14. Prof. K. K. Mathur, B.Sc. (Hons., Lond.), A.R.S.M., Professor of Geology, Benares Hindu University, Benares.
 15. G. Clarke, Esq., F.I.C., F.C.S., C.I.E., Director of Agriculture, United Provinces, Lucknow.
 16. P. B. Richards, Esq., A.R.C.S., F.E.S., Entomologist to the Government, United Provinces, Cawnpore.
 17. R. L. Sethi, Esq., M.Sc., B.Sc. (Agri., Edin.), M.R.A.S. (Lond.), Economic Botanist to the Government, United Provinces, Cawnpore.
 18. Prof. H. D. H. Drane, M.Sc., Ph.D., A.M.I.E.E., A.M.I. Chem.E., Principal, Harcourt Butler Technological Institute, Cawnpore.
 19. Prof. C. A. King, B.Sc. (Hons. Eng., Lond.), A.R.C.Sc., M.I.M.E., Principal, Engineering College, Benares Hindu University, Benares.
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APPENDIX B
LIST OF OFFICE-BEARERS AND MEMBERS
OF THE COUNCIL

President

1. Prof. M. N. Saha, D.Sc. (Cal.), F.R.S., F.A.S.B., F. Inst. P., P.R. Scholar, Professor of Physics, Allahabad University, Allahabad.

Vice-President

2. Prof. N. R. Dhar, D.Sc. (Lond.), Docteur ès Sciences (Paris), F.I.C., I.E.S., Professor of Chemistry, Allahabad University, Allahabad.
3. Prof. K. N. Bahl, D. Phil. (Oxon.), D.Sc. (Punjab), Professor of Zoology, Lucknow University, Lucknow.

Treasurer

4. Prof. D. R. Bhattacharya, M.Sc. (Alb.), Ph.D. (Dublin), Docteur ès Sciences (Paris), Professor of Zoology, Allahabad University, Allahabad.

General Secretaries

5. Prof. P. S. MacMahon, B.Sc. (Oxon.), M.Sc. (Manchester), F.I.C., Professor of Chemistry, Lucknow University, Lucknow.
6. Prof. A. C. Banerji, M.Sc. (Cal.), M.A. (Cantab.), F.R.A.S. (Eng.), I.E.S., Professor of Mathematics, Allahabad University, Allahabad.

Foreign Secretary

7. Prof. Ch. Wali-Mohammad, M.A. (Cantab.), M.A. (Punjab), Ph.D. (Göttingen), I.E.S., Professor of Physics, Lucknow University, Lucknow.

Other Members of the Council

8. Prof. K. C. Mehta, Ph.D. (Cantab.), M.Sc. (Punjab), Professor of Botany, Agra College, Agra.
9. Prof. G. Clarke, Esq., F.I.C., F.C.S., C.I.E., Director of Agriculture, United Provinces, Lucknow.
10. Prof. H. D. H. Drane, M.Sc., Ph.D., A.M.I.E.E., A.M.I., Chem. E., Principal, Harcourt Butler Technological Institute, Cawnpore.
11. Prof. K. K. Mathur, B.Sc. (Hons., Lond.), A.R.S.M., Professor of Geology, Benares Hindu University, Benares.
12. Prof. Dr. Luxmi Narayan, D.Sc. (All), Reader in Mathematics, Lucknow University, Lucknow.

APPENDIX C

LIST OF NAMES OF MEMBERS WHO WERE IN THE ROLLS OF THE ACADEMY ON THE 31ST OF OCTOBER, 1931

1. Prof. A. C. Banerji, M.A., F.R.A.S., I.E.S., Professor of Mathematics, Allahabad University, Allahabad.
2. Prof. M. N. Saha, F.R.S., Professor of Physics, Allahabad University, Allahabad.
3. Prof. N. R. Dhar, D.Sc., I.E.S., Professor of Chemistry, Allahabad University, Allahabad.
4. Prof. D. R. Bhattacharya, D.Sc., Ph.D., Professor of Zoology, Allahabad University, Allahabad.
5. Prof. J. H. Mitter, M.Sc., Ph.D., Professor of Botany, Allahabad University, Allahabad.
6. Prof. Andre Weil, D.Sc., Professor of Mathematics, Muslim University, Aligarh.
7. G. Chatterjee, Esq., M.Sc., Meteorologist, Upper Air Observatory, Agra.
8. Prof. K. C. Mehta, M.Sc., Ph.D., Professor of Botany, Agra College, Agra.
9. Prof. K. K. Mathur, B.Sc., A.R.S.M., Professor of Geology, Benares Hindu University, Benares.
10. Prof. C. A. King, B.Sc., A.R.C.Sc., M.I.M.E., Principal, Engineering College, Benares Hindu University, Benares.
11. P. B. Richards, Esq., A.R.C.Sc., F.E.S., Entomologist to the Government, United Provinces, Cawnpore.
12. R. L. Sathe, Esq., M.Sc., B.Sc., M.R.A.S., Economic Botanist to the Government, United Provinces, Cawnpore.
13. Dr. H. D. H. Drane, M.Sc., Ph.D., A.M.I.E.E., A.M.I., Principal, Harcourt Butler Technological Institute, Cawnpore.
14. Dr. Luxmi Narayan, D.Sc., Reader in Mathematics, Lucknow University, Lucknow.
15. Prof. Ch. Wali-Mohammad, M.A., Ph.D., I.E.S., Professor of Physics Lucknow University, Lucknow.

16. Prof. P. S. MacMahon, B.Sc. M.Sc., Professor of Chemistry, Lucknow University, Lucknow.
17. Prof. K. N. Bahl, D.Phil., D.Sc., Professor of Zoology, Lucknow University, Lucknow.
18. Prof. B. Sahni, D.Sc., Sc.D., F.L.S., F.A.S.B., Professor of Botany, Lucknow University, Lucknow.
19. G. Clarke, Esq., F.I.C., F.C.S., C.I.E., Director of Agriculture, United Provinces, Lucknow.
20. Salig Ram Bhargava, Esq., M.Sc., Reader in Physics, Allahabad University, Allahabad.
21. Dr. R. N. Ghosh, D.Sc., Physics Department, Allahabad University, Allahabad.
22. Dr. Kanakendu Majumdar, D.Sc., Physics Department, Allahabad University, Allahabad.
23. G. R. Toshniwal, Esq., M.Sc., Physics Department, Allahabad University, Allahabad.
24. Rabindra Nath Chaudhuri, Esq., M.Sc., Mathematics Department, Allahabad University, Allahabad.
25. Shri Govind Tewari, Esq., M.A., Mathematics Department, Allahabad University, Allahabad.
26. Dr. P. L. Srivastava, Ph.D., Reader in Mathematics, Allahabad University, Allahabad.
27. Dr. H. R. Mehra, Ph.D., Reader in Zoology, Allahabad University, Allahabad.
28. Dr. Ram Saran Das, D.Sc., Zoology Department, Allahabad University, Allahabad.
29. S. K. Dutta, Esq., M.Sc., Zoology Department, Allahabad University, Allahabad.
30. Shri Ranjan, Esq., M.Sc., Reader in Botany, Allahabad University, Allahabad.
31. Dr. Satyeshwar Ghosh, D.Sc., Chemistry Department, Allahabad University, Allahabad.
32. Dr. Nihal Karan Sethi, D.Sc., Professor of Physics, Agra College, Agra.
33. Dr. T. Vijayaraghavan, D.Phil., Mathematics Department, Muslim University, Aligarh.
34. S. K. Mukerjee, Esq., M.Sc., Professor of Physics, Agra College, Agra.
35. Prof. K. C. Pandya, D.Sc., Professor of Chemistry, St. John's College, Agra.

36. Prof. Rudolf Samuel, D.Sc., Ph.D., Professor of Physics, Muslim University, Aligarh.
37. Dr. W. Dudgeon, Ph.D., Ewing Christian College, Allahabad.
38. Dr. Sam Higginbottom, Principal, Agricultural Institute, Naini (Allahabad).
39. Dr. Iqbal Kishen Taimni, Chemistry Department, Allahabad University, Allahabad.
40. Dr. S. Dutt, D.Sc., Reader in Chemistry, Allahabad University, Allahabad.
41. K. P. Chatterjee, Esq., M.Sc., A.I.C., F.C.S., Reader in Chemistry, Allahabad University, Allahabad.
42. D. D. Kosambi, Esq., Benares Hindu University, Benares.
43. Dr. S. K. Mukerjee, D.Sc. (Lond.), Reader, Botany Department, Lucknow University, Lucknow.
44. A. C. Chatterjee, Esq., Chemistry Department, Lucknow University, Lucknow.
45. Dr. S. M. Sane, Reader in Chemistry, Lucknow University, Lucknow.
46. H. P. Chaudhury, Esq., M.Sc., Lucknow University, Lucknow.
47. Dr. Avadesh Narayan Singh, D.Sc., Department of Mathematics, Lucknow University, Lucknow.
48. Dr. D. B. Deodhar, D.Sc., Reader in Physics, Lucknow University, Lucknow.
49. Dr. S. S. Nehru, I.C.S., Deputy Secretary to Government, United Provinces, Lucknow.
50. Dr. B. M. Gupta, D.Sc., Deputy Public Analyst to Government, United Provinces, Lucknow.
51. S. D. Seth, Esq., M.A., Christ Church College, Cawnpore.
52. P. K. Dey, Esq., I.A.S., Plant Pathologist to Government, United Provinces, Nawabgunj, Cawnpore.
53. The Hon'ble Sir S. M. Sulaiman, LL.D., Judge, High Court, Edmonstone Road, Allahabad.
54. Dr. B. Mirza, D.Phil., Director, Zoological Laboratories, Muslim University, Aligarh.
55. Dr. D. N. Forman, M.D., Jumna Dispensary, Allahabad City.
56. R. K. Asundi, Reader in Physics, Muslim University, Aligarh.
57. F. D. Murad, Esq., Department of Physics, Muslim University, Aligarh.
58. Prof. Robert F. Hunter, D.Sc., Ph.D., Professor in Chemistry, Muslim University, Aligarh.
59. D. P. Bhattacharya, Esq., M.Sc., Bareilly College, Bareilly.

60. Vashishta Bhargava, Esq., B.Sc. (Hons.), M.Sc., I.C.S., Assistant Magistrate and Collector, Budaun.
61. B. N. Ghosh, Esq., Prof. of Physics, St. Andrew's College, Gorakhpur
62. B. D. Puri, Esq., M.A., Professor, Thomason Civil Engineering College, Roorkee.
63. K. C. Bhatia, Esq., I.C.S., Joint Magistrate, Shahjahanpore.
64. Saradindu Basu, Esq., M.Sc., Meteorologist, Poona, 5.
65. C. Maya Das, Esq., M.A., B.Sc. (Edin.), I.A.S., Principal, Agricultural College, Cownpore.
66. M. F. Soonawala, Esq., M.Sc., Professor of Physics, Maharajah's College, Station Road, Jaipur (Rajputana).
67. L. P. Mathur, Esq., Professor, St. John's College, Agra.
68. W. G. P. Wall, Esq., M.Sc., Associate I.E.E., M.R.S.T., I.E.S., Inspector of Schools, Allahabad Division, Allahabad.
69. Ram Kishore Sharma, Esq., M.Sc., Physics Department, Ewing Christian College, Allahabad City.
70. Prof. B. Dasannacharya, Ph.D., Prof. of Physics, University, Benares.
71. C. B. Gordon, Esq., M.A., Christ Church College, Cawnpore.
72. D.V. Gogate, Esq., Prof., Physics Department, Baroda College, Boroda.
73. Mata Prasad, Esq., Professor of Inorganic and Physical Chemistry, Royal Institute of Science, Bombay.
74. Dr. P. K. Kichlu, Department of Physics, Govt. College, Lahore.
75. Dr. Subba Rao, D.Sc. (Lond.), Professor of Physiology, Medical College, Mysore.
76. Dr. C. Srikanta, B.A., D.Sc. (Zurich), Professor of Chemistry, Medical College, Mysore.
77. Prof. W. J. Hansen, Allahabad Agricultural Institute, Naini E. I. R., Allahabad.
78. D.H. Ramchandra Rao, Esq., B.E., A.M.I.E., Engineer, Allahabad University, Allahabad.
79. J. L. Sathe, Esq., I.C.S., Director of Industries, U.P., Cawnpore.
80. Satyendranath Ray, Esq., M.Sc., Lucknow University, Lucknow.
81. N. C. Mehta, Esq., I.C.S., Director of Agriculture, U.P., Lucknow.
82. Dr. S. S. Joshi, Professor of Chemistry, Benares Hindu University, Benares.
83. Dr. S. C. Bagchi, B.A., LL.D., Principal, Law College, Calcutta.
84. Nobendu B. Banerjee, Esq., M.Sc., 5 B, Couper Road. Lucknow.
85. Shyama Charan, Esq., M.Sc. (Lond), Professor, Agra College, Agra.
86. G. N. Banerji, Esq., The Scientific Instrument Coy. Ltd., Allahabad.
87. Suresh Chandra Deb, Esqr., M.Sc., C/o Dr. M. N. Saha, 7 Beli Road, Allahabad.

APPENDIX D

LIST OF MEMBERS WHO WERE REQUESTED BY THE COUNCIL TO RECOMMEND SUITABLE JOURNALS FOR THE ACADEMY

1. Prof. K. K. Mathur, B.Sc., A.R.S.M., Professor of Geology, Benares Hindu University, Benares.
2. G. Clarke, Esq., F.I.C., F.C.S., C.I.E., Director of Agriculture, United Provinces, Lucknow.
3. Prof. C. A. King, B.Sc., A.R.C.Sc., M.I.M.E., Principal, Engineering College, Benares Hindu University, Benares.
4. Prof. B. Sahni, D.Sc., Sc.D., F.L.S., F.A.S.B., Professor of Botany, Lucknow University, Lucknow.
5. Prof. P. S. MacMahon, B.Sc., M.Sc., Professor of Chemistry, Lucknow University, Lucknow.
6. Prof. D. R. Bhattacharya, D.Sc., Ph.D., Professor of Zoology, Allahabad University, Allahabad.
7. Prof. N. R. Dhar, D.Sc., I.E.S., Professor of Chemistry, Allahabad University, Allahabad.
8. Prof. M. N. Saha, F.R.S., Professor of Physics, Allahabad University, Allahabad.
9. Prof. A. C. Banerji, M. A., F.R.A.S., I.E.S., Professor of Mathematics, Allahabad University, Allahabad.
10. Prof. J. H. Mitter, M.Sc., Ph.D., Professor of Botany, Allahabad University, Allahabad.

APPENDIX E

LIST OF MEMBERS OF THE PUBLICATION COMMITTEES

MATHEMATICS

Prof. A. C. Banerji, M.A., F.R.A.S., I.E.S., Professor of Mathematics,
Allahabad University, Allahabad.

Prof. Andre Weil, D.Sc., Professor of Mathematics, Muslim Univer-
sity, Aligarh.

PHYSICS

Prof. M. N. Saha, F.R.S., D.Sc., Professor of Physics, Allahabad
University, Allahabad.

Prof. Ch. Wali-Mohammad, M.A., Ph.D., I.E.S., Professor of Physics,
Lucknow University, Lucknow.

CHEMISTRY

Prof. N. R. Dhar, D.Sc., I.E.S., Professor of Chemistry, Allahabad
University, Allahabad.

Prof. P. S. MacMahon, B.Sc., M.Sc., Professor of Chemistry, Lucknow
University, Lucknow.

ZOOLOGY

Prof. D. R. Bhattacharya, D.Sc., Ph.D., Professor of Zoology,
Allahabad University, Allahabad.

Prof. K. N. Bahl, D.Phil., D.Sc., Professor of Zoology, Lucknow
University, Lucknow.

BOTANY

Prof. B. Sahni, D.Sc., Sc.D., F.L.S., F.A.S.B., Professor of Botany,
Lucknow University, Lucknow.

Prof. K. C. Mehta, Ph.D., M.Sc., Professor of Botany, Agra College,
Agra.

MINING AND GEOLOGY

Prof. K. K. Mathur, B.Sc., A.R.S.M., Professor of Geology, Benares,
Hindu University, Benares.

AGRICULTURE

Prof. C. Maya Das, M.A., B.Sc., I.A.S., Principal, Agriculture College,
Cawnpore.

Dr. Sam Higginbottom, Principal, Agricultural Institute, Naini
(Allahabad).

ADDITIONAL ABSTRACTS OF THE PROCEEDINGS

It was resolved that the President be requested to hold the ordinary meetings of the Academy as far as possible on holidays but not on Sundays, so that it may be convenient for the Christian members as well as for members not residing in the town where a meeting is to be held to attend it.

It was resolved that some of the ordinary monthly meetings of the Academy of Sciences be held at university and educational centres other than Allahabad, where there is a sufficient number of members to form a quorum and where the members are prepared to make arrangements for the meeting.

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1. Dr. H. R. Mehra, Ph.D.
2. Dr. T. Vijayaraghavan, D. Phil.

The following members were elected office-bearers and the Members of the Council for the year 1931 in the annual meeting held on 27th of November, 1931.

President

1. Prof. M. N. Saha, D.Sc., F.R.S.F.
Inst. P.F.A.S.B.

Vice-Presidents

2. Prof. N. R. Dhar, D.Sc., F.I.C., I.E.S.
3. Prof. K. N. Bahl, D.Sc., D.Phil.

Hony. Treasurer

4. Prof. D. R. Bhattacharya, M.Sc., Ph.D., D.Sc.

General Secretaries

5. Prof. P. S. McMahon, B.Sc., M.Sc., F.I.C.
6. Prof. A. C. Banerji, M.A., F.R.A.S., I.E.S.

Foreign Secretary

7. Prof. Ch. Wali-Mohammad, M.A., Ph.D., I.F.S.

Other Members of the Council

8. Prof. K. C. Mehta, Ph.D., M.Sc.
9. Dr. S. S. Nehru, M.A., Ph.D., I.C.S., M.L.C.
10. Prof. H. D. H. Drane, M.Sc., Ph.D., A.M.I.E.E.
11. Prof. K. K. Mathur, B.Sc., A.R.S.M.
12. Dr. Luxmi Narayan, D.Sc.
13. Dr. D. N. Foreman, M.D.
14. Prof. B. Sahni, D.Sc., Sc.D., F.I.S., F.A.S.B.
15. Dr. P. L. Srivastava, M.A., D.Phil.
16. Prof. André Weil, D.Sc.

MESSAGES FROM SOME OF THE EMINENT SCIENTISTS OF THE WORLD

PROF. ALBERT EINSTEIN writes :

‘ Herr M. N. Saha, dem die Physik insbesondere die Astrophysik so wertvolle Beiträge zu verdanken hat, hat mich von den hohen Zielen der ins Leben gerufenen Akademie der Wissenschaften in Allahabad benachrichtigt. Ich begrüße diese Gründung mit wärmster Sympathie und mit grosser Erwartung. In der kurzen Zeit, seit welcher einzelne Inder sich den modernen exakten Wissenschaften zugewendet haben letztere schon wertvolle Anregungen von diesen Männer erfahren. Ich erinnere nur an den Physiker und an den Physiologen Bose. Aber längst ist es noch nicht so weit, dass die grossen Schätze wissenschaftlicher Begabung gehoben wären oder voll zur Entwicklung gelangten, welche in Ihrem alten Kuturvolke schlummern. Möge durch Ihre Bemühungen recht nur die geistige und wirtschaftliche Entwicklung Ihres Landes sondern auch die Klärung der tiefen Fragen wirksam gefördert werden, welche die ewig rätselvolle Natur an uns richtet.’

English Translation :

Mr. M. N. Saha, to whom Physics, particularly Astrophysics, is indebted for many valuable contributions, has reported to me about the Academy of Sciences which has been called into existence at Allahabad with a high object. I welcome this inauguration with the warmest sympathy, and with great expectations. Within the short period of time since individual Indians have turned their attention to modern exact sciences, science has received much valuable stimulus from them. I call to my mind the physicist and the physiologist Bose (Sir J. C. Bose)

F. 3.

But still the great treasures of scientific gifts slumbering in your nation, who possess such an ancient culture are very far from having been unearthed, or fully developed. May you, by your efforts, not only further the spiritual and economic developments of your country but also clear up the deeper questions which Nature, ever full of riddles, is presenting to us.

LORD RUTHERFORD of Nelson, Cavendish Professor of Physics (Cambridge), writes :

'I have been very interested to hear from my friend Professor Saha that it is the intention to start an Academy of Sciences at Allahabad. Corresponding societies of this type have played an important part in the development of scientific interests of the community not only in this country but in Europe generally. I am sure that the foundation of a similar society in your Province would serve a very useful purpose in promoting the development of science. I send a message of good wishes for the success of your academy. May it grow and prosper !'

PROF. A. SOMMERFELD, Professor of Theoretical Physics (Munich), writes :

'When I came to India two years ago I decided not to miss Allahabad, this centre of old Indian history and of modern scientific development. I was received very kindly by my friend M. N. Saha between the rivers Ganges and Jumna. I feel sure that Allahabad will be just the right place for the proposed foundation of an Academy of Sciences. I send my sincere wishes for your new organisation and for a splendid future of Indian Science.'

SIR A. S. EDDINGTON, Professor of Astronomy (Cambridge), writes :

'I send the heartiest good wishes on the occasion of the inauguration of the Academy of Sciences at Allahabad. Speaking especially for Mathematical and Physical Sciences we owe to India some of the finest contributions to progress in recent

years. It is my earnest hope that the Academy may aid to develop the great potentialities of India, spreading the knowledge and love of science, encouraging learning and research, discovering and recognising original thoughts and genius, and providing a centre of organisation and discussion.'

PROF. ROBERT A. MILLIKAN, Director of the Norman Bridge Laboratory (California, U. S. A.), writes:

'I am greatly delighted to learn from your (Prof. Saha's) letter just received that an Academy of Sciences is being started at Allahabad for the promotion of scientific knowledge in India.

On behalf of the California Institute of Technology, which I have the privilege of officially representing, and on behalf of the scientists of our Western America, of whom I am one, I am sending herewith cordial greetings and best wishes for the new movement. It is a particularly significant event, not only for India but for the World, for the World's most supreme need is the discovery and dissemination of knowledge about the nature of this world of which we are a part, and its processes. India is making notable contributions, as this year's Nobel prize award abundantly demonstrates, and she is sure to make larger ones when her energies are more fully directed towards the purposes which your organisation is designed to foster.'

PROF. MANNE SIEGBAHN (Upsala University, Sweden, and Secretary of the Nobel Committee), writes:

'By everyone who has followed the flourishing scientific activity in the different centres of India, the foundation of the Academy of Sciences at Allahabad will be greeted as an event of the utmost importance. The international world within the science has all reasons to see with great satisfaction and pleasure all efforts to strengthen the national activities to the common object of the human knowledge. When I feel entitled to congratulate you upon the foundation of the Academy, this the highly important and wonderful research work emanated from Allahabad in that scientific subject.'

years. It is my earnest hope that the Academy may aid to develop the great potentialities of India, spreading the knowledge and love of science, encouraging learning and research, discovering and recognising original thoughts and genius, and providing a centre of organisation and discussion.'

PROF. ROBERT A. MILLIKAN, Director of the Norman Bridge Laboratory (California, U. S. A.), writes :

'I am greatly delighted to learn from your (Prof. Saha's) letter just received that an Academy of Sciences is being started at Allahabad for the promotion of scientific knowledge in India.

On behalf of the California Institute of Technology, which I have the privilege of officially representing, and on behalf of the scientists of our Western America, of whom I am one, I am sending herewith cordial greetings and best wishes for the new movement. It is a particularly significant event, not only for India but for the World, for the World's most supreme need is the discovery and dissemination of knowledge about the nature of this world of which we are a part, and its processes. India is making notable contributions, as this year's Nobel prize award abundantly demonstrates, and she is sure to make larger ones when her energies are more fully directed towards the purposes which your organisation is designed to foster.'

PROF. MANNE SIEGBAHN (Upsala University, Sweden, and Secretary of the Nobel Committee), writes :

'By everyone who has followed the flourishing scientific activity in the different centres of India, the foundation of the Academy of Sciences at Allahabad will be greeted as an event of the utmost importance. The international world within the science has all reasons to see with great satisfaction and pleasure all efforts to strengthen the national activities to the common object of the human knowledge. When I feel entitled to congratulate you upon the foundation of the Academy, this is due to the highly important and wonderful research work which has emanated from Allahabad in that scientific subject.'

which is my own. From the pleasant cooperation with a number of young prominent students from India I have also got the conviction that the immediate future of the Academy must be viewed as most favourable and promising.'

PROF. DR. R. GOLDSCHMIDT, Director of the Biological Section, The Kaiser Wilhelm Institute (Berlin), writes :

'I regard it as a great privilege to send you my sincere birth-day greetings. When I visited Allahabad University I was greatly impressed by the excellent organisation of the University, the good conditions of the laboratories, and the high standard of performance, not less by the fine spirit of idealism and keen interest in the progress of science, which I found among the excellent professors. I wish sincerely that the youngest academy will become a center of that lofty enthusiasm for spiritual performance, so characteristic of the Indian people, without which no human progress is possible. May your work lend new truth to the old saying—Ex oriente lux.'

SIR J. C. BOSE (Calcutta) writes :

'I send you my best wishes for the success and prosperity of the proposed Academy of Sciences, Allahabad.'

SIR C. V. RAMAN (Calcutta) writes :

'I am glad to learn from your (Prof. Saha's) letter of 30th October that your scheme for an Academy of Sciences at Allahabad is going ahead. As a Great Teacher has told the world, a tree is judged by its fruits. If, as I expect it will, the Academy serves to stimulate research at Allahabad and elsewhere in the United Provinces, its foundation will be amply justified. I write to convey my warmest good wishes for the success of the new venture.'

PROF. E. S. GOODRICH, Professor of Biology (Oxford), writes

'It is with pleasure that I write to express my hope that the decision to found an Academy of Sciences at Allahabad may

be successfully carried out. The fine series of volumes recently issued and containing the works of members of the University of Allahabad are evidences of the wide range of learning studied, and a gratifying proof of the high level reached by them in original research. With confidence I look forward to the Academy becoming a valuable centre for the encouragement and advance of scientific knowledge.'

SIR P. C. RAY (Calcutta), writes:

'I welcome the inauguration of the Academy of Sciences. Allahabad has already become an intellectual centre for Upper India. Moreover, the United Provinces is the seat of as many as five Universities with their Faculties of Sciences. There is thus ample material for an independent Academy of Sciences. I wish it success and prosperity.'

SIR JAMES WALKER (Edinburgh), writes:

'I hear with great pleasure that an Academy of Sciences is to be established at Allahabad. It is a natural outcome of the growth and striking success of Indian Science, and I send my hearty good wishes for its continued prosperity.'

INAUGURAL MEETING

PRESIDENT'S ADDRESS

SPEECH BY PROF. M. N. SAHA, D.Sc., F.R.S., PRESIDENT
OF THE ACADEMY OF SCIENCE, THE UNITED PROVINCES
OF AGRA AND OUDH

AT THE INAUGURAL MEETING OF THE ACADEMY OF SCIENCE,
ALLAHABAD, MARCH 1, 1932.

YOUR EXCELLENCY, FELLOWS AND MEMBERS OF THE ACADEMY,
LADIES AND GENTLEMEN,

Before I deliver my presidential address, I should like to accord, on behalf of the Academy and myself, a hearty welcome to our Patron, His Excellency Sir William Malcolm Hailey, G.C.I.E., K.C.S.I., I.C.S., to our Inaugural Meeting. His very presence is indicative of a bright future for our institution. Our Secretary, Prof. A. C. Banerji, has already described to you the great personal interest His Excellency has taken in bringing the Academy to existence. We offer him our heartfelt thanks and hope that he will continue to take the same interest in the years to come. His Excellency has been instrumental in getting for us an annual grant of Rs. 4,000 from the Government, and it is very encouraging to find that in spite of the present economic depression, the grant is being continued.

In his opening address to the Seventeenth Session of the Indian Science Congress held at Allahabad on January 2, 1930, His Excellency was pleased to emphasize on the necessity of starting an Academy of Science in the following words :

"Now I am well aware that there are definite limits to the extent to which the efforts of our research workers or students can be directed to these problems (of economic and utilitarian value), and I am also well aware that coordination of their labours cannot be directed from outside. It must be voluntary

effort, or at the most, it must be advice given by some Academy of Science which will contain authoritative representatives of all the specialised branches of scientific activity now at work in the province. But if some form of visible coordination could be attempted, and if it could be proved to the public that science workers were contributing some at least of their energies in the direction I have suggested, then I believe we should have a far more effective case in calling for that public support and private liberality on which the further progress of scientific work must depend."

In starting the Academy of Science, we have been guided by the noble sentiments contained in the above quotation, and you will find from a perusal of our Memorandum that though the primary object of the Academy is cultural development, service of the community on the lines suggested by His Excellency also forms a principal object of our Academy.

MESSAGE OF GOOD WILL FROM THE LEADING SCIENTISTS OF THE WORLD

We approached the leading scientists of the world including Prof Einstein and Lord Rutherford for messages of hope and good will. Most of them were kind enough to respond to us, and I take this opportunity of thanking them for their kindness. From the messages which our Secretary, Prof. P.S. MacMahon, has just read out to you, you will see that we have started on our career with blessings from the greatest living exponents of Science in the world.

I hope that in future, the President will entertain you, on the occasion of the Anniversary meeting, with a review of the progress made here or outside on the line of scientific work in which he is interested, this being the practice in all learned societies. But this being the inaugural meeting, you will kindly excuse me for speaking in general terms.

THE BEGINNINGS OF SCIENCE

Like every other achievement of the human mind, the beginnings of science are to be traced to the ceaseless struggle

which man has to wage for his life and existence against Nature, disease, beasts and fellow-men. Though many useful discoveries, which we may call scientific, were made by men in the prehistoric and the remote historic past, very little evidence of a scientific mind can be traced in the earlier societies. But man came to realise early that for waging these wars successfully, power is necessary, and that real power consists in the knowledge of 'Nature' and of 'Things.' The objects of perception to our senses, "Time and Space, Life and its processes, the phenomena of Nature," early became objects of speculation and investigation amongst the primitive sages.

Animism, magic, the period of nature gods and of abstract gods mark the various earlier phases of cultural development. But progress was not continuous, very often the human mind got enmeshed in its own creation, and failed to proceed further.

Nearly two thousand years ago, a great philosopher in Greece, Socrates, pleaded for the emancipation of the human mind and was able to convert a number of young men to his views. But the idea was not favoured by the more conservative fellow-citizens; on the contrary, he was prosecuted on the charge of corrupting the morals of young men, and was condemned to death. But Plato, the disciple of Socrates—taking advantage of the changed political conditions—openly preached that "*Organised and systematic thinking was more necessary for the Nation's welfare than military training and athletic sports.*" He founded the first Academy in the world to give effect to his ideas, and gathered round him a large number of intelligent young men, the most prominent being Aristotle. There was just then the necessity for such a clear formulation of principles. For though cultivation of knowledge was regarded in some measure as conducive to human progress, studies were generally confined to fine arts and literature. When the Greek philosophers created the Nine Muses to preside over the various branches of knowledge, no subject which is now classed as scientific was found amongst them. The healing art, the observation of stars, and other dignified subjects were left to

the care of priests who guarded their lore jealously from the public gaze; the application of brain power to everyday affairs of life was thought to be unworthy of serious study by the enlightened. The magic men who tried to find out "Secrets of Nature" were regarded with suspicion, and sometimes burnt as being dangerous to public welfare. The legend of Prometheus served to remind such men of their fate in the other world, even if they could escape justice in the present.

THE EARLY INFANCY OF SCIENCE

But except for a brief period, the early infancy of science was full of trouble and misgivings for its future. Plato was succeeded by his great disciple Aristotle, who had a wonderful and modern mind, and wrote on Physics, Biology, and Mathematics. Then came the period of the famous Alexandrian school which gave us Euclid (the Geometrician), Ptolemaios (the Astronomer), Eratosthenes who first measured the diameter of the Earth, and Hero, the forerunner of James Watt; elsewhere there were Archimedes, Hipparchus, and others. The contribution of these philosophers to the stock of knowledge was very substantial and if these various organisations had been allowed to continue, probably the age of science would have dawned on Europe much earlier. But in spite of their high philosophy, the Greeks could not achieve political unity, and fell under the attack of Roman Imperialism. Though Rome was appreciative of the values of Greek culture, she regarded Militarism as the highest of professions and scientific pursuits were regarded as worthy only of second-rate-men, of subject-people and slaves. The result was that progress in scientific knowledge was almost at a standstill during five hundred years of Roman domination. Then came the social revolt amongst the suppressed nationalities and the human society underwent a regrouping under the ideals of Christianity. But the early Christian Fathers wanted to instil a blind respect for the scripture into the minds of the laymen, and the Christian Hierarchy showed great intolerance to the spirit of the freedom

of thought displayed by scientific workers. Science became practically dead in Europe when the last of the Alexandrian school, the learned Hypatia, was murdered by an infuriated mob at the instigation of the Patriarch of Alexandria.

SCIENCE IN THE EAST

While these developments were taking place in the West, the East was not idle. In fact, recent discoveries in archaeology prove that a good deal of the knowledge of the Greeks was derived from Egypt and Babylon, to which countries Greek youths used to journey about the fifth or the sixth centuries before the Christian era for the sake of knowledge. In fact, Socrates was not the first philosopher to preach rationalism, he was preceded by a long line of thinkers, notably of the various Ionian schools. Though it is not possible fully to reconstruct the past, it is evident that the Eastern nations including the ancient Persians and Hindus were to a large extent influenced by Babylon. But civilization in the two old culture centres had become stereotyped. The youthful Greek mind gave an entirely new turn to the old knowledge by their creation of the science of statics and geometry, and the geometrisation of the astronomical lore. But above all, by their rationalistic views, they paved the way for the greater discoveries of modern times. The contemporary Hindu mind in the East was responsible for the creation of the sciences of algebra, trigonometry, and arithmetic. There are reasons to believe that under Buddhistic influence the healing art received great encouragement, and investigations on the curative properties of herbs and minerals, which early led to alchemy and ultimately to chemistry in Europe, seem to have originated in India. With the rise of Islam, the Arabs became the inheritors of the old world knowledge, which they enriched by substantial contributions of their own. In fact, during the Middle Ages, the Arabs alone kept the torch of knowledge burning, and their centres of learning in Spain and Egypt were frequented by students from the youthful nations of the

West, whose thirst for knowledge could not be satisfied by study of the scriptures alone.

REVIVAL OF SCIENCE IN THE WEST

During all these centuries, the West was on the downward track. The position is very ably summarized by the mathematician Jacobi:

"History knew a midnight, which we may estimate at about the year 1000 A.D., when the human race had lost the arts and sciences even to the memory. The last twilight of paganism was gone, and yet the new day had not begun. Whatever was left of culture in the world was found only with the Saracens, and a Pope eager to learn studied in disguise at their universities, and so became the wonder of the West. Finally Christendom, tired of praying to the dead bones of the martyrs, flocked to the Saviour Himself, only to find for a second time that the grave was empty and that Christ had risen from the dead. Then mankind too rose from the dead. It returned to the activities and the business of life; there was a feverish revival in the arts and in the crafts. The cities flourished, a new citizenry was founded. Cimabue rediscovered the extinct art of painting; Dante, that of poetry. Then it was also that great courageous spirits like Abélard and Saint Thomas Aquinas dared to introduce into Catholicism the concepts of Aristotelian logic, and so was founded the scholastic philosophy. But when the *Church took the science under her wing, she demanded that the forms in which they were be subjected to the same unconditioned faith in authority as were her own laws.* And so it happened that scholasticism, far from freeing the human spirit, enchained it for many centuries to come, until the very possibility of free scientific research came to be doubted. At last, however, here too daylight broke, and mankind, reassured, determined to take advantage of its gifts and to create a knowledge of nature based on independent thought. The dawn of this day in history is known as the Renaissance or the Revival of Learning."

THE RENAISSANCE MENTALITY

The Renaissance mentality was entirely different from that of the old world with its respect for scriptures, and veneration for tradition. The new spirit strove after freedom in every direction, and its greatest cultural achievement, according to Spengler was the discovery of the science of Dynamics, or the science of time changes, which the ancient nations, with their ahistoric time-sense, were incapable of comprehending. This discovery, which is due to the great Galileo, one of the finest products of the Renaissance period, was far greater in its importance than his more spectacular invention of the Telescope which enabled man to peep farthest into Space, and gave a deathblow to the geocentric theory of the Universe. For as an instrument of thought, the Galilean dynamics has been of the greatest service in the study of Nature-phenomena. The symbols for the new knowledge of dynamics were created by Descartes, Leibnitz and Newton. Newton, in particular showed that the mysterious motions of planets which troubled the sages of Chaldea for several millennia and the mediæval Europeans for several centuries, could be explained with the aid of dynamics and the law of gravitation, discovered by him.

So great was the impression created by the method of the new science that Huygens, the great Dutch contemporary of Newton, writing in 1680, says, "In true philosophy, we shall conceive the cause of all natural phenomena in terms of mechanics. This we must do or for ever renounce the hope of understanding anything of physics."

STUDY OF NATURE-PHENOMENA

The logical outcome of the Renaissance mentality ought to have been an immediate return to an intensive study of Nature-Phenomena. But mental inertia takes time to be overcome, and the serious application of the human mind to the study of experimental sciences came more than two hundred years later—in fact, with that great drama in human history, viz., the French Revolution which sought to enthrone a Goddess of Reason in

the human mind in place of the inflexible God of the Scriptures. It cannot be said that Nature-Phenomena did not appeal to mankind in early times; on the contrary, they appealed rather too strongly to the human imagination, so much so that during one period of their cultural development, almost all ancient nations deified Nature-Phenomena. We could only wish that this regard for Nature took a less reverential turn. I shall illustrate my point by one example. At the present time, it is inconceivable to think of civilization without electricity. Energy in the form of electricity can be adopted to every day needs of the human society, and there is no doubt that the science of electricity has immense possibilities for the development of the resources of the world. Nay, even the savant, the physicist and the chemist cannot explain the phenomena of Nature he is concerned with without invoking the proton and the electron. But just a hundred years ago, electricity was rather an obscure subject of investigation by the scientist in his laboratory. It made its first appeal to the human mind in the thunder of atmospheric clouds, and with naive simplicity was symbolised in prehistoric times as a great God, Indra, or Zeus the Thunderer. But if instead of erecting altars to the god of electricity or writing beautiful hymns for his propitiation, the phenomena were scientifically investigated as the Ionian Philosopher, Thales of Miletus, advocated in 700 B. C., or Benjamin Franklin carried out two thousand five hundred years later in America, the science of electricity might have developed long ago, with consequences on human history of which we can only dream now.

BACON'S 'NEW ATLANTIS'

It cannot be said that the Philosophers of the Renaissance Period were unappreciative of the benefits likely to arise from experimental methods of research and had not insisted on greater attention being paid to it. Just three hundred years ago, Francis Bacon described to the European public a picture of the great future which may be created by cultivation of the experimental methods of research, and by a nation-wide

organisation for applying the knowledge of science to the needs of the nation. In his *New Atlantis*, published in 1626, he pictured a carefully-planned and well-founded college consisting of thirty-six 'Fellows' divided into groups, each group being charged with a special department of enquiry or research. The field of enterprise was to embrace the whole of Nature, and was to be both theoretical and practical, with a view, on the one hand, of unravelling the cause of things and on the other, of obtaining such a knowledge of facts as would lead to new discoveries and inventions. One-half of the Fellows were to be employed in collecting from foreign countries, and abstracting from books and from mechanical arts and liberal sciences all that had been previously discovered or invented. The rest of the Company, consisting of six groups, were to be variously employed in trying new experiments, tabulating former experiments and results, and endeavouring to draw forth conclusions useful 'for Man's life and knowledge and aphorisms.'—('Extract from the Record of the Royal Society.')

DID BACON PRESENT AN UTOPIA ?

Three hundred years of history now separate us from the times when Bacon, a keen student of history and a shrewd observer of contemporary events wrote his '*New Atlantis*.' He appealed to the State for a liberal encouragement of science in the hope that an intense study of science and its application to life would give rise to a better world. There is no reason to believe that these ideas were ever seriously regarded by the contemporary rulers to whom they were primarily addressed. These rulers must have regarded him, and (others like him) as one of those unpractical visionaries who sometimes trouble the ruling class with their unrealisable Utopias. But has not the subsequent course of human history completely vindicated Bacon's ideas of the Future ?

A great change has come over the world. The material side of this change is thus described by a modern American historian :

"It requires a great effort to imagine our present world, with its factories, railways, steamboats, telephones, airplanes, and

radio, to have been at any other time, different from what it is to-day. Yet these wonderful mechanisms are but a century old, and the product of a great change in human affairs known as the 'Industrial Revolution.' Until its advent the economic life of the world for countless ages had been much the same. A Greek of the time of Pericles, coming to France in the reign of Louis XIV, would have seen little to astonish him in the methods of farming, manufacturing, trading, building and transportation. Should he, however, come to America of the twentieth century, he would literally believe himself to be in an enchanted world. He would see things made with lightning rapidity by machines, wheat cut and the sheaves bound without human labor, vehicles speeding along without horses, ships moving through water without sails, houses brilliantly lighted without lamps, birdlike contrivances flying in the air, and hear and see some one speaking thousands of miles away."

"The term 'revolution' is generally applied to a popular uprising that is characterized by violence of speech and action. During the economic revolution no speeches were made, no conventions were held, no battles were fought. Nevertheless, this silent change, by altering radically the conditions of life for millions of human beings, may be truly regarded as the greatest of all revolutions in history, and as marking the end of the civilization of the past and the beginning of the civilization of the present and of the future." "It was a revolution," a modern writer says, "which has completely changed the face of modern Europe and of the New World, for its introduction a new race of men—the men who work with machinery instead of with their hands, who cluster together in cities instead of spreading over the land in villages and hamlets; the men who trade with those of other nations as readily as with those of their own town; the men whose workshops are moved by the great forces of nature instead of the human hand, and whose market is no longer the city or the country, but the world itself."

This historian only stresses on the material side of the great change. But he forgets to emphasize the fact

that the great Industrial Revolution which has enabled mankind as a whole to fight better with Nature, and exploit the Earth to better advantage for the sustenance of human life has been largely due to the great discoveries in the physical and biological sciences of the last three hundred years. The productivity of the earth has increased enormously, not only in Industry but also in Agriculture, where by an intense application of the scientific methods, the yield has in some countries been as much as quadrupled. Hence instead of there being a shortage of foodstuff for the needs of the increasing population of the world, as some gloomy prophets predicted fifty years ago, there has been a perplexing glut in many countries. The discoveries in the biological sciences have enabled mankind to combat diseases more successfully and to improve the general level of health immensely. According to a competent authority, there is now in European countries less mortality amongst the children of labourers than there was amongst the children of royalties a hundred years ago.

These great achievements are mostly due to the individual efforts of small groups of men who worked out their self-imposed problems in their laboratories or workshops, sometimes amidst great want and poverty, and never got the state aid they sorely needed. But the services of Science in producing a better world have not been properly appreciated. On the contrary, Science is held responsible for many of the evils of the present-day world.

SCIENTIFIC WORLD-PICTURE OF TODAY

Socrates was presented with a cup of hemlock for on the charge that he was corrupting the morals of the youth of his native city. In the past science has been, and is still, charged with corrupting the morals of individuals, as well as of groups represented by capitalists, and politicians. Only the other day, a Professor in the United States of America was dismissed from his post for teaching Darwin's Theory of Evolution!

The charges have therefore to be faced; unfortunately the man of science is too much absorbed in his own work, and being crude in his expressions, he cannot rouse the heart to

the same pitch of emotion as the poet or the platform speaker. His defence has therefore not been very effective. But the charges of corruption are based entirely on a misunderstanding of the aims and objects of science. The ideas of virtue and morality are not absolutely rigid; they change with culture-epochs, and have been widely different as men passed from savagery to animism, from animism to the period of nature gods, from nature gods to rigid monotheism, and from the era of codified religions to the era of science. They change like a moving picture, as the world-conception varies. The scientific world-picture of today is very different from the times when codified religions which still govern the thoughts of majority of mankind were formed. Most of the religions regard the Earth as the centre of the Universe, and man as the central object of the Creator's attention, for according to the Scripture "he was made according to His own image." The men who are curious enough to know the secrets of Nature were threatened with the doom of Prometheus, or the fate of Adam and Eve whose miseries were due to their eating of the fruit of knowledge. In addition, certain nations or castes or groups were taught to regard themselves as the specially chosen of God and provided with special mandate to exercise spiritual and political power over others. Even in the enlightened twentieth century, these ideas find credence in some form or other. But in the light of the world-picture of today as revealed through science such ideas can no longer be entertained. The Earth has been found to be a tiny fragment of the Sun from which it separated billions of years ago, and is cruising in space in the train of the Sun to an unknown Destiny. The Sun is only a second class denizen of the galaxy of stars called the Milky Way which again is one amongst many thousand billions. Who can believe that man, the insignificant inhabitant of a tiny planet attached to a second class star amongst myriads of others, could be the special object of interest to the Creator? If there be any Creator, the qualities ascribed to Him by most scriptures can only be the grossest libel on Him. The effect of biological studies has been equally

devastating. It has shown that man is the last evolution product of a race of mammals and by no means perfect, as poets and law-givers in their vanity thought him to be. He has developed the brain and certain other organs which give him a preponderating superiority over other beasts, but who can deny that there may be other superior forms of life in the island universes about us which are as superior to man on this Earth as Gulliver's Houyhnhnms were over their manlike slaves, the Yahoos? Indeed the anthropological sciences tell us that the brute instincts are ever present in man, and the fastings, the flagellations, the prayers and the moral codes are methods which we try for suppressing the outburst of these feelings.

Though the findings of science are very devastating on our cherished moral codes, and on the traditional forms and beliefs of religion, society and politics, should we act on the principle "Where ignorance is bliss, it is folly to be wise"? If we are ever to regard culture as desirable nobody can deny that science has done a great service in developing the human mind.

SCIENTIFIC WORLD-PICTURE OF TO-MORROW

In these days, it is rather risky to prophesy about the future world-picture, for prophecy has never been successful except in the case of astronomy. But still as hankering after prophecies seems to be an inborn craving, I would follow the usual rule, with certain amount of caution. There is no reason to believe that the era of great scientific discoveries is drawing to a close. Everybody who has grappled with some scientific problem knows how crude our methods are and how incomplete our results. The world is full of puzzles, as the Sage said despairingly two thousand five hundred years ago :

Nor him, now any light
Shall any gazer see with mortal eyes,
Or any searcher know by mortal mind;
Veil after veil will lift—but there must be
Veil upon veil behind.

—Edwin Arnold—*The Light of Asia*,

It is lucky that the world has not accepted this counsel of despair,* for then progress would not have been possible. It has on the other hand chosen to follow Goethe's maxim expressed in the beautiful lines of Tennyson

"To strive, to seek, to find, and not to yield."

But at the same time, this ought to have a sobering influence on the man of science or on such who may think that the riddles of Nature are all nearing solution. The true investigator is reminded at every stage of the famous saying of Newton :

"But to myself it seems that I have been but as a child playing on the seashore, now finding some prettier or more beautiful shell than my companions while the unbounded Ocean of Truth lies unexplored before me."

Up to this time, the physical sciences have been most effective in changing man's life. The wonderful progress in these sciences has been due to three causes :

- (1) To their intimate contact with every-day needs of life which have attracted a large number of workers to this field.
- (2) To the development of experimental methods, which means a combination of the brain and the hand, and therefore leads to practical philosophy.
- (3) To the creation of those wonderful instruments of human thought, viz., dynamics and infinitesimal calculus which have enabled the workers to form a synoptic mental picture of the whole set of Nature-Phenomena, and to concentrate the whole power of the brain to their study.

But at the present time, these methods are in a state of flux. The classical ideas were quite all right as long as we were content with studying physical phenomena in this world

* There are reasons to believe that Mahayazism is due to a revolt from this attitude of "*Laissez Faire*" regarding investigations of Nature. Nagarjuna who is supposed to be the founder of Mahayanism (First Century B.C. to First Century A.D.) professed alchemy, and is credited with the discovery of many medical drugs with which he wished to combat diseases of the human body.

of ours, but as Einstein showed they fail miserably when we try to correlate events in this world with events in the other worlds (Stars) about us. The three main basic conceptions in the Galilean dynamics are those of mass, time, and space, but like an iconoclast Einstein has shown that their classic conceptions are insufficient. He has given new ideas for describing world-events which are known as the Principle of Relativity. But the second stage of development of his ideas is more profound than the first inasmuch as he has tried to show that all physical phenomena are simply the metrical properties of a space-time manifold. He thus strives to obtain a synoptic view of the phenomenal world which will include electricity, gravitation, atomistics, and other nature-phenomena. But he does not claim that his attempt is final in its form, the idea has been started and it has to be worked out according to a programme in which the cooperation of the mathematician, the astronomer, and the physicist is required. The last eclipse expedition has proved that the gravitational deflection is not twice the classical deflection, as worked out by Einstein on the first form of his theory, but $5/2$ times as large. Also the form and extent of the universe worked out by him seems not to conform to facts; at the present time, a large number of eminent investigators favour the idea of the expanding universe worked out by Le Maitre. All these investigations are indicative of profound changes in our fundamental concepts of Physics.

It is a rather abrupt step to turn from the macroscopic world of stars to the microscopic world of the atom, but discoveries in this direction have not been less startling or far-reaching. The nineteenth century marks a great epoch in human history, as of all previous centuries it witnessed the greatest development in our knowledge of Nature. The sciences of electricity, heat, light and various branches of chemistry, with their far-reaching influence in modifying the course of human life, were in fact developed in this century. But to the historian of 2500 A.D., even the nineteenth century will appear to be less glorious than the present one. This historian will look upon the nineteenth century as the one in

which the science of atoms was fully developed, and the beginnings of the study of nature-phenomena were just made. It was a century in which men could trace all ideas to the old heroes of antiquity, and all the credit they could claim was that they were responsible for the development of these ideas. But the twentieth century has witnessed the birth of ideas which are rather startling in their novelty. The atom is no longer found to be the ultimate unit, out of which this polyglot world has been formed, but it has been found, largely due to the efforts of the Cambridge School (J. J. Thomson and Lord Rutherford) that all atoms are the compounds of two primordial elements, the proton, the atom of positive electricity and the electron, the atom of negative electricity. The methods of classical dynamics involving the principles of determinism and causality have been found to be wanting, and we are proceeding to a new order of things indicated by such titles as the quantum theory and wave mechanics. The idea of quanta, first started by Planck, acted like a magic wand in the hands of Bohr, and led to the most wonderful explanation of the structure of the atom out of protons and electrons, and of their radiant properties. But in this field, classical dynamics has been found insufficient (Heisenberg), and more satisfactory results have been obtained from a new formulation of dynamics, as well as from the wave-conception of matter (De Broglie. Schrödinger). But none of these forms of dynamics appear to be final. We seem at the present time to be on the verge of a great synthesis of ideas which will include the theory of relativity, the quantum theory, as well as the phenomena of gravitation, and such a synthesis cannot but materially affect our ideas of the universe.

The influence of biology on the human events has not been so striking as that of the physical sciences and my ignorance of the subject prevents me from speaking on the possibilities of the subject with anything like authority. But that very ignorance allows me a certain amount of licence which has usually been the privilege of newspapermen. The results of biology are nevertheless of the greatest interest to every one of us, as they are directly concerned with the problems

of the mysterious phenomena of life. Already the few striking results which the biologists have given to the world—Darwin's Theory of Evolution and Mendel's Principle of Selection,—have been very far-reaching in their effects. Investigations have shown that lack of certain ingredients in our food induces far-reaching changes in our activity, for example—a deficiency in iodine is thought to lead to idiocy, and deficiency in manganese is reported to lead to the loss of maternal instincts. The future biological discoveries seem to be full of the greatest possibility in modifying human life. For example, Prof. Haldane in his *Daedalus* considers a "human society (certainly in a jocular vein) fifty years hence in which babies will be produced by ectogenesis, and politicians will be cured of their perversities by some form of injection." Time alone can decide whether such prophecies are going to be fulfilled.

At present, the methods in biology are entirely different from those of physical science, but probably the two will be linked more intimately in the future. It is quite refreshing to find that the idea of linking up these two sciences by a unitary method first occurred to one of our countrymen, viz., Sir J. C. Bose, though his work has raised rather heated controversies. But the history of science has shown that such is usually the fate of all pioneering works. The idea is not at all idle: for only recently Dirac, a very promising worker in mathematical physics at Cambridge, has expressed the opinion that the quantum theory may afford a possibility of explaining the life processes on physical grounds. The progress can be accelerated by a hearty co-operation between biologists and physico-chemists. Owing to the abandonment of the ideas of causality and determinism by the physicists themselves in recent years, the methods in physical sciences and biology seem to be nearing each other.

STATE AID IS GIVEN AFTER THREE CENTURIES

The state-aid for science, to which Bacon advocated, has taken nearly three hundred years to materialize. There

are indications that the Governments of all countries have realised, especially after the Great War, that science is a force to reckon with, and is probably the main factor in future developments. The organisation in every 'civilized' country is confirmatory of this belief. Take, for example, a country like England. The Universities are now regarded as active centres of creative research instead of being regarded as places of refuge for monkish scholars, or self-sufficient pedants. The school courses have been reorganised for a better propagation and dissemination of scientific ideas amongst the masses. Large research funds, both private as well as public, have been created for helping deserving workers. In addition to the old scientific societies, more have been created, very often with state aid, for discharging functions which Bacon assigned to his college of thirty-six fellows. A large number of national institutions and services have been brought into existence for work which cannot be undertaken by private individuals but require nation-wide and centralized organisation and therefore state aid: such are the National Physical Laboratory, the Medical Research Council, the National Observatories, the various scientific services like the Zoological, the Geological, and Agricultural. In addition, the great industrial concerns have organised large-scale research laboratories for not only solving industrial problems, but also for undertaking problems of an academic nature. All these imply a faith that the future progress of mankind is largely dependent on the application of science to every-day problems of life, not only in the field of national economy, but also in politics and social organisation.

WHAT SCIENCE CAN DO FOR INDIA ?

In India, unfortunately, Science evokes no hope in the hearts of her political leaders. Millions of our people live a miserable life of poverty and semi-starvation, but the causes of poverty have never been scientifically investigated. Whatever the factors may be, the fact remains that there is an underproduction of foodstuffs, and other main necessities of life and

whatever is produced is very unequally distributed. A competent economist has estimated that in India, where primitive methods are still applied, the outturn of agricultural products per acre is scarcely a fourth of that in countries like Belgium or Java, where scientific methods are applied on an intensive scale. It was therefore a great step forward when the late Viceroy, Lord Irwin, founded the Agricultural Research Council with the object of enabling competent specialists to study the latest scientific methods and applying them to Indian conditions; for increased production in agriculture will not only give a fuller meal to the hungry millions, but will enable India to resume her position as the greatest exporter of agricultural products. Notable results have already been achieved particularly in the field of sugarcane cultivation, but it is a matter of great regret that the Agricultural Research Council has been the first victim of the policy of retrenchment.

Many views have been suggested for producing a better world; one extreme view-point which finds great favour in our country is to go back to Nature. But this can scarcely be called a promising solution, for history has shown that even in the past, when communication was hundred times more difficult, Chinese walls were never able to secure complete isolation for a nation. At the present time, the world is fast becoming one economic as well as one cultural unit. Hence if we do not keep pace with the rest of the world, we shall be reduced to the position of the Yahoos. We cannot think of any "Back to Nature programme" which can dispense with railroads, and other quicker methods of transport, with the printing press, the power-generating devices; therefore a certain amount of industrialisation is unavoidable. For the last two decades the world has been progressing, in times of war, and the more so in times of peace, towards increasing application of scientific methods to human problems. For the development of industries and agriculture in the country, the natural resources, and sources of power must be fully developed and exploited. This requires a more intelligent and well-educated group of politicians who can put forward a "Five-or

ten-year plan," for constructive national development and possess the will-power to carry it through. The problems are formidable:—Most parts of India are lacking in coal, but there is sufficient potential waterpower, and electrification has a great future. The quality and quantity of agricultural products have to be brought to the level of the world's improved standard by intensive and cooperative application of scientific methods. The rapidly deteriorating animal stock has to be improved. How a contemptuous disregard of the powers of science leads to disaster is well illustrated by the ruin of indigo plantation in India by the production of synthetic indigo in German laboratories. The sugar industry in our country has to be kept alive by heavy protective tariffs, as the cost of production in this country, due to continuation of the old crude methods is nearly double that of Java. Instances can be multiplied, but I hope that what I have said will bear out my contention.

WHAT AN ACADEMY OF SCIENCE CAN DO?

It is clear that a large number of scientific organisations is necessary for handling these nation-wide programmes. The schools, the colleges, the universities, the technical institutes, the scientific services and establishments should be so organised that they can fit into the scheme. An Academy of Science can do a great deal by educating public opinion, undertaking particular problems, and bringing out scientific workers in various fields for discussion and cooperative research. But the main function of the Academy should be towards cultural improvement, by contributions to human knowledge.

THE PRICE OF IGNORANCE

In fact, it is probably not realised by many of our leaders that the main cause of our backwardness is ignorance, and mere political freedom, without a determined programme for removing the curse of illiteracy, and for dissemination of the knowledge of science and economics can never lead to a better

world. Many countries in the world, particularly some in South America are politically independent; still the population are mostly the wage-slaves of groups of capitalists, and the Presidents are merely nominees of some one boss or the other. We continue to be exploited mainly because the public are ignorant of the economic values of the mineral and agricultural resources of our country. An example not widely known will suffice. Fifty years ago, manganese ores in the Central Provinces, which now constitute one of the chief sources of wealth of that province, used to be brought in cartloads, and used for paving the roads. The ores were recognised by certain tourists who happened to pass through Nagpur. At this time, Sir Robert Hadfield's discovery of manganese steel was becoming known, and metallurgists were looking for richer deposits of manganese, when the knowledge of the presence of rich manganese ores in C.P. became known. Companies were floated, and sites were bought for trifling sums of money. The price of ignorance in this case, measured in money, will amount to about a hundred crores. Schemes of electrification in this province, which have a great potential future, are being retarded, because there is not a sufficiently well-educated public to appreciate its advantages, and get proper control exerted on the managing bodies.

SCIENCE IN THE SERVICE OF COMPETITIVE NATIONALISM

I have tried to give a picture of what science has done for the world. According to a competent authority "There is scarcely any limit to what can be done in the way of producing a good world, if only men would use science wisely."—(Bertrand Russell, "*Icarus*.")

But history has shown that science has more often been used for promoting the interests of selfish dominant groups. It has enabled favoured nations to organise war and to exploit the weaker nations on a much grander scale than ever was possible. In the words of the scoffing demon of Goethe's 'Faust,' science may be said to have made the beastly side of human nature more bestial.

As illustrations, we may point out the use of poison gas, and other forms of chemical warfare during the great World War. Another striking example is the starvation of whole nations by blockades, which was possible only on account of scientific inventions.

Before the Great War, the attitude of the ruling powers towards science was one of indifference (of course, there were exceptions). The patronage shown towards science after the Great War is not generally actuated by a feeling of general benevolence towards mankind, but is frankly for the sake of aiding competitive nationalism, and aggressive imperialism. In this respect, the history of science resembles the early history of Christianity which began as a great socialistic movement with the object of improving the relations between man and man, and producing a better world; but was taken under the protection of ruling powers as soon as they felt that such a course would be to their advantage; and was subsequently used to hamper the very ideal which it sought at first to enshrine in the world.

In future wars or struggles, this cruel and destructive side of science will, it is feared, be revealed in an even more lurid light.

These incidents have led to a general distrust of science as conducive to human happiness, and some have even gone so far as to propose a return to Nature, and a French critic advocated the same treatment to scientific workers as was meted out by the Papacy during the middle ages.

IS A WORLD WITHOUT KNOWLEDGE A BETTER WORLD?

The dangers just referred to have led many thinking men to the belief that science instead of leading us to the dawn of a happier era in human history, may be leading us to the twilight of modern civilization to be followed by a dark and unfathomable night. But blame can scarcely be attached to science if such a disaster ever happens. No scientific man ever holds that knowledge can be a substitute for virtue. Both are necessary for a stable society. But it is not realised

that the experiment of producing a better world by excluding all knowledge was actually performed many times in history by champions of different religious systems and we have accurate record of the experiments carried out by the apostolic fathers during the early days of Christianity, and continued also during the Middle Ages. "*Credo quia absurdum*," said one of the greatest of them. But did it succeed in averting epidemics, famines, or oppressions? History says an emphatic 'no.' Even if we exclude the Inquisition, and the terrible religious wars which arose out of such a mentality, there were other great tragedies to which such ideas very often led. When epidemics broke out, the priestly class in all countries used to gather people in places of worship and asked them to offer prayers to God Almighty. The result was that owing to congestion, the infection spread with alarming rapidity and led to such vast-scale tragedies as the "Black Death." This is a tragedy caused by benevolence untempered by knowledge. I think most will now prefer the opposite extreme of knowledge without benevolence, which is applied by the quarantine officer who forcibly takes away an infected person from his people and puts him in a segregation camp. Knowledge is based on 'Free thinking' and virtue on 'Right thinking,' and many will probably like to follow the motto of the Scandinavian Philosopher which is inscribed on the portals of the University of Upsala - "Free thinking is good, but Right thinking is better."

WHAT IS RIGHT THINKING?

But "What is Right thinking?" Though there are many evil things on which all shades of opinion are agreed, most of the human tragedies, national, social or civic are, as Hegel aptly remarked, due to conflict between Right and Right, i.e., what is right to one group, has appeared just the opposite to the other group. Is it not possible to find out an absolute standard of the Right, independent of time, locality or tradition? Most of the present views of the Right are derived from the so-called Scriptures, law books and social codes;

they still govern the majority of mankind though they date from distant antiquity; but if we discard the pretension of divine origin which is claimed for them by Pundits of the orthodox class, it should be admitted that they were based upon insufficient knowledge and analysis of nature, of life, and of the actions of the human mind. Is it not possible to subject these last to a searching scientific analysis, and find out absolute standards? Spinoza thought that this was quite feasible.

"Not to laugh or weep over the actions of men but simply to understand them, and to contemplate their affections and passions, such as love, hate, anger, arrogance, pity and all other disturbances of the soul, not as vices of human nature, but as properties belonging to it in the same way as heat, cold, storm and thunder belong to the 'atmosphere. For these, though troublesome, are yet necessary, and have certain causes through which we may come to understand them and thus by contemplating them in their truth, gain for our minds as much pleasure as by the knowledge of things that are pleasing to the sense."

Scientific methods have been applied by scholars to the study of subjects of more human interest like Civics, Politics, Economics, History, Social Eugenics, and Experimental Psychology, and it is generally the custom to designate them under the collective name of 'Anthropological or Social Sciences.' They deal with the 'Human Mind,' and therefore form a natural sequel to the study of the physical sciences which deal with nature, and biological sciences which deal with individual life. These sciences deal with collected human-life and invade the forbidden grounds of religion, social codes and politics, and some of their findings alarm the vested interests to the same extent as Copernicus's heliocentric theory of the solar system frightened the churchmen of the fifteenth century. But for the good of the world, it is not only desirable that they should be pursued with greater vigour, but their lessons should be applied with great determination to all forms of human activity.

In fact it has appeared to many thinking men that many of the evils of the present-day world are due to the non-adaptation of the human organisations to the changing conditions of the world. Owing to improved methods of communication and to much better contact between its different parts, the world is fast becoming one economic and cultural unit. But the politicians still persist in their Olympian attitudes.

Before the great World War, the politician was at the stage where the Physicist found himself before the time of Archimedes, or better in the days of Homer and Hesiod. His country was his Olympus, his own people were his gods, all others were demons, barbarians fit only to be secured against the stroke of the sword, or exploited as helots. The Great War, and all other wars before it were the result of such a mentality, but the Great War exceeded all previous wars in the intensity of destruction and havoc because science placed more power in the hands of men. But it did one great thing, it exposed the absurdity of international quarrels. When the late M. Clemenceau visited Egypt, and was taken round the Pyramids, he commented rather sarcastically on the 'vanity of the Egyptian Pharaohs who built huge stone monuments with slave labour for the sake of housing their Ka (Soul). He was reminded by a Cairo paper that if the Soul of Cheops, the builder of the Great Pyramid could be released from his stony sepulchre, he could have retorted that the Treaty of Versailles and the expenditure on Dreadnaughts, and on military armaments and sacrificing the finest youths of the country before the bloody altar of Nationalism, were far greater absurdities; as one-tenth of the money wasted in the war, if spent on internal development of the natural resources, would have given every belligerent country a far greater amount of security and prosperity than the politicians ever dream to achieve by methods peculiar to them.

THE PRESENT WORLD—ONE ECONOMIC AND CULTURAL UNIT

At present, the fact is only slowly dawning on the public that the world is fast becoming one great economic unit. A crash in Wall Street leads to a strike in the Bombay Mills, and

unemployment in Lancashire leads to a fall in the price of jute in Bengal, and ultimately to Hindu-Muslim riots. A prosperous year in India leads to an increased consumption of foreign goods. Over-population in Japan and China causes a clash in Manchuria between the two peoples, and is fraught with menace towards Australia and Insular India and to world peace. The rulers of countries cannot therefore persist in their Olympian attitude towards other nations—they must become earth-wide in their outlook. But this is prevented by the present faulty system of education which seeks to perpetuate the mediæval mind, and brings only a small percentage of the population under the humanising influence of science. The result is disastrous; those who are called upon to guide the destinies of nations are mostly men with a rigid outlook, quite unfit to fathom the depths of present-day troubles, or analyse the intricacies of political and economic issues, and are unable to hold out any programme of reconstruction. In our country, the result is competitive communalism; among the free nations—a tense atmosphere of competitive nationalism, and between the ruler and subject nations—a spirit of revolt against aggressive imperialism.

But economic and scientific studies show that the world has resources enough for her whole population, and if there be a rational programme of production, and a programme of judicious and equitable distribution, nobody should suffer from hunger, privation, and can even afford to have much better amenities of life. But for this purpose, rivalry amongst nations and communities should give way to co-operative construction, and the politician should hand over many of his functions to an international board of trained scientific industrialists, economists, and eugenists, who will think in terms of the whole world as a unit, and devise means by which more necessities of life can be got out of the earth; the whole production should be controlled by scientific industrialists, and the distribution should be supervised by the economists. The eugenists should devise means for assigning a fixed quota of population to each geographical unit, which it should not be allowed to exceed.

It may seem to be a dream, but is feasible provided the educational programme of the coming generations is thoroughly revised. A new educational scheme should be devised by a World's Congress of foremost thinkers like Bergson, Einstein, Bertrand Russell, Smuts, Spengler, and others, with the special objective of weeding out mediæval passions from the minds of the coming generation, and for training them to a proper grasp and sufficient appreciation of the beauty and powers of science. The joy of life for the grown-up men will be provided not in designing means for the plunder or exploitation of their fellow-men in various ways but in administering to their needs, and in free development and display of the finer faculties of the mind.

Would this dream be realized, or is it possible that mankind will ever have to fight against the Doom of Tantalus? For myself, my conviction is that the Greek Philosopher who created the story of Pandora and her box is right in so far as he says that the Angel of Hope has always been asked to remain with Mankind. I wish finally to finish with a poem which best expresses the feelings:

NATURA ENIM NON NISI PARENDO VINCITUR

At first men try with magic charm
 To fertilize the earth,
 To keep their flocks and herds from harm
 And bring new young to birth.

Then to capricious gods they turn
 To save from fire or flood;
 Their smoking sacrifices burn
 On altars red with blood.

Next bold philosopher and sage
 A settled plan decree,
 And prove by thought or sacred page
 What Nature ought to be.

But Nature smiles—a Sphinx-like smile—
 Watching their little day
 She waits in patience for a while—
 Their plans dissolve away.

Then come those humbler men of heart
 With no completed scheme.
 Content to play a modest part,
 To test, observe, and dream.

Till out of chaos come in sight
 Clear fragments of a Whole;
 Men, learning Nature's ways aright,
 Obeying, can control.

The great Design now glows afar;
 But yet its changing Scenes
 Reveal not what the Pieces are
 Nor what the Puzzle means.

And Nature smiles—still unconfessed
 The secret thought she thinks
 Inscrutable she guards unguessed
 The Riddle of the Sphinx.

—W. C. D. DAMPIER-WHETHAM,
History of Science.

PATRON'S ADDRESS

SPEECH BY HIS EXCELLENCY SIR MALCOLM HAILEY, G.C.I.E.,
K.C.S.I., I.C.S., GOVERNOR OF THE UNITED
PROVINCES OF AGRA AND OUDH

AT THE INAUGURAL MEETING OF THE ACADEMY OF
SCIENCES, ALLAHABAD, MARCH 1, 1932

You have generously given me some credit for assistance rendered in the foundation of your Academy. I fear that it has been but slight; and I could wish that the difficult circumstances in which we all now find ourselves had enabled us to give you greater help. But none the less it is gratifying to find that you have successfully surmounted early difficulties, and have found your project so advanced that you have been able to hold your inaugural meeting this year. You yourselves no doubt feel that it may not be easy, just at first, to achieve the full activity you may desire, for finances are bound to present an obstacle. But in work of the kind which you are undertaking, the spirit of the worker is really more important than the extent of his resources; a time will surely come when expansion is possible, and I am confident that you will in due season see your society occupy an important place in the intellectual life of the province, originating inquiry, co-ordinating scientific effort, and pooling the results achieved.

I suppose, gentlemen, that we have now all passed the stage when we think it worth while either to dilate on what science (in the sense in which we now use the word) has achieved for us, or to emphasize the necessity for ministering to the needs of those who are engaged in research. We accept without question its great achievements in the century that has passed, and acknowledge the necessity for assisting it to fresh efforts for the future. Even those whose brains are not cast in a mould which enables them to appreciate the mysteries of gravitational deflection, or the

exact relation of the proton to the atom, or the possibilities of finding in the quantum theory an explanation of biological processes, are quite prepared to accept the need for supporting scientific research. They cannot read the book of science themselves; but they know that it contains much that has been of great value to mankind; and they know equally that there are an infinite series of chapters still to be written and of benefits still to be realized. I am led however to the following thoughts. Though the world will no doubt see an increasing number of people whose mental equipment embraces a knowledge of some one branch of science, and who are thereby better able to appreciate the wider generalizations at which scientific workers arrive, yet I fancy that even in the distant future you will always find large numbers of people whose brains are not of that particular constitution which enables them to take a real interest in scientific work. In one direction science will grow more specialized; in another more abstruse; and this will in itself limit the number of persons who can make anything like a serious study of it. It may be a suggestion somewhat distressing to scientists, who look forward to a time when they will bring the whole intellectual world under their domination; but I am not sure myself that the people of the world at large will be any the worse off because large numbers will always resist the efforts to give them a scientific education. All you really want to secure is that the men of a real scientific bent have full sway for their activity; that institutions for research are properly supported and adequately equipped; and that scientists themselves can be put in the way of such organization of their energies as will avoid wastage of effort. I agree that there must be an autonomy of science; much of what the scientist is doing is so far beyond the comprehension of the lay mind that any form of dictation or even direction from outside is unthinkable. But given that, it seems to me that you must be content to allow science to work its own leaven on the mass intelligence of the world. We have seen in our own generation the rapidity of the infiltration its effects, and the powerful influence it exerts in breaking up old

concepts and rationalizing the mass outlook. That is bound to be a continuing process.

I am coming now to the inference from the picture I have drawn. The world will always contain a great number of people—it may well be a majority of people—who will have come unconsciously under scientific influences, and who will partake in the benefits conferred by scientific progress, but will nevertheless be in something of a questioning attitude towards men of science. They will not want to know more about electrons and protons; they will be asking whether science cannot do something more definite to secure human happiness. A mere addition to knowledge, as such, does not necessarily make the world happier. Improvements in mechanical advance (using this word in its widest sense) can do something; but their range seems limited. Our lives may be fuller, but is not quite certain that we are really happier for the comparative annihilation of distance or the more rapid transference of thought. On the other hand, I admit that improvement in health is very definitely an addition to human happiness. I suppose that we would all agree, that what we look for in the future is the assistance of science,—if it can give it—in securing a more rational manipulation of human nature. Can it, for instance, give man a domination over his own passions equal to that which it seems to be achieving over the physical forces of the external world? We used to think of the domination of passion as an ethical problem for the individual; but it is the unhappy tendency of modern times to translate individual into mass action, and collections of people now seem to find excuse for passionial absurdities in the mass which we should certainly recognize as harmful in the individual. It is perhaps a common-place, but it is nevertheless true, that a generation which ridicules its predecessors for their scientific ignorance, has shown emotional irrationalism on a larger scale than the world has ever seen before. I do not refer merely to the fact that it made a world war; perhaps that was only a temporary ebullition of world passion; but its subsequent performances in tariff wars, in dealing with its principal medium of exchange,

or with the problem of disarmament, certainly do not seem to show that it has grown in mental balance. Can science again do anything to rectify the psychology of fear which now seems to dominate the world—fear of national ruin, and fear of material insecurity both to the individual and to collections of people? A sense of insecurity, or a sense of thwarted life, physical or material, is a real source alike of mischief and unhappiness. Can science again do anything to aid the moralist in removing some of the malevolence which does actually seem to form a part of common human nature and which continues to thwart the progress made by the growth of the social sense? It is possibly physiological in origin, which may make scientific attack in the end more efficacious than purely moral suasion. Our conclusion must I suppose be that science is really only one of the agencies which are available for removing these somewhat basic disturbances in the human balance. But of truth, we need the services of any agency we can command. I do not think that any of us would like to contemplate a future in which mankind, though it knows a great deal more, and has far more activities and perhaps far more amenities than it enjoys at present, will nevertheless come short of the kind of progress we want it to achieve; I mean, a progress in the basic facts of life on which its contentment and its happiness depends. It is somewhat disturbing fact that mankind has not so far achieved an improvement in that direction at all commensurate with what it has achieved in scientific or mechanical knowledge. You must pardon these speculations; if they are disturbing they are not querulous. There is an immense deal to be achieved by men who devote themselves to the branches of thought in which you specialise. Every success you record will have its effect direct or indirect on the human race. If we can link up the energies of scientific men with the other agencies which are working for our betterment, then perhaps we may get a synthesis of effort which will in time mould the human character into something nobler than the shape which it now presents.

In proposing a vote of thanks to His Excellency Sir Malcolm Hailey, Dr. K. N. Bahl made the following remarks :

I am sure I am voicing the feelings of every one present here this evening when I say that we are extremely grateful to Your Excellency for the trouble you have taken in coming over to Allahabad to inaugurate the U. P. Academy of Sciences. We, the members of the Academy, are deeply sensible of the honour you have done us by coming over here to encourage us at a time when we all realise, there are momentous questions constantly requiring your close attention. Your presence here this evening is a great moral support to the Academy and we hard-headed men of science, fully realise that the moral support of the Governor of the Province is an earnest of the material support to follow in due course.

As Your Excellency has pointed out, science has not only contributed in the past to the amelioration of human conditions by its wonderful discoveries and inventions, but will continue to do so in future, for scientific men all over the world are engaged in solving problems which have vast practical possibilities. But I believe the influence of science is definite in the other direction to which also Your Excellency has referred. Science has a direct influence upon the temper of the mind. For the scientific spirit applied to human affairs is bound to lead to improvement in all relations of men within the nations, as well as in the mutual relations of nations. For our welfare, we need the discipline of science, the development of the spirit of detachment, of the pursuit of truth and knowledge without prejudices which distort reason

If our country is to take its rightful place among the nations of the world it is our duty to provide our share in the advancement of knowledge and if we are to lead a happy, prosperous and progressive life we must cultivate the scientific spirit. We hope the Academy which Your Excellency has inaugurated this evening will help in the fulfilment of these aims.

We are deeply thankful to Your Excellency for your good wishes and it only remains for me now formally to propose a hearty vote of thanks in which I am sure every one present here will join.

In seconding the vote of thanks, Dr. H. Drane, Principal, the Harcourt Butler Technological Institute, U.P., Cawnpore, said :

"Your Excellency, the interest which you have shown in this Academy since its inception is a matter of pleasurable pride and encouragement to each of its members. We appreciate your interest all the more greatly because we know it to be surely and well founded, not simply in a realisation of the material benefits which science may, in this twentieth century, confer upon the conditions of human existence,—or in a desire for the increase of knowledge for its own sake,—but equally in a knowledge of that modern necessity—a scientific outlook, in dealing with those larger social and economic problems, with which the work of government, in any part of the world, is nowadays beset. If any of us failed previously to consider the nature of your interest, the address which you have just delivered leaves us without room for doubt, and fully confirmed in the beliefs which I have just outlined.

But this is not all—I feel that our appreciation has been further and particularly enhanced since we have found your interest to be practical, sincere and energetic. Its practical nature has been shown by your placing, at the disposal of the Academy, funds which permit it effectively to function. The sincerity of your interest has been shown by the carefully thought out advice which you have from time to time given to its members: at the time of inception of the Academy you indicated the importance in modern life of the application of the results of scientific investigation to the problems of daily existence; you accordingly directed the attention of members to the necessity of giving a bias to their investigations in the direction of those problems which confront the welfare of the community as represented by the health, agriculture, and industries of these provinces. You have now laid before us

a number of fresh and stimulating thoughts which considerably widen the field of scientific enquiry. Your invocation of science to the help of the moralist—or at least your query whether help can so be given—particularly seems to open a very wide field for speculation and enquiry. The Academy indeed continues fortunate, in its commencing stages, to have the benefit of your sympathy and your ripe experience of men and affairs.

Other countries have realised the necessity of fostering scientific advance, and applying not only the results of scientific investigation, but also the methods of science in many of the matters of governmental procedure. Your patronage, therefore, of this Academy brings these provinces, in this regard, into the forefront of progress amongst states and provinces in India,—a position from which with your guidance, it cannot readily be dispossessed. Realising from this the unique position of the Academy, we may hope, in no vain manner, that its progress will be parallel with that of earlier established organisations of the character elsewhere.

The energy and kindly interest with which you fulfil the office of Patron is exemplified by the trouble which you have taken to come over to Allahabad from the seat of your Government in Lucknow, to address us at this inaugural meeting. For all and for each of these reasons we owe to you most grateful thanks and an assurance of appreciation of the services which you are so adequately bestowing upon the Academy in your capacity as Patron. I have therefore pleasure and good reason to support this vote of thanks proposed to you on behalf of the Council and members.

THE FIRST ANNUAL MEETING

The First Annual Meeting of the Academy of Sciences was held on Friday the 27th of November, 1931, at 5-30 p.m. in the Senate Hall of the Allahabad University.

Sir C. V. Raman was invited to deliver an address on the "Spin of Light."

The President in introducing Sir C. V. Raman paid a glowing tribute to him for the very valuable and epochmaking researches he had carried out in the realm of Physics. The President then requested Sir Venkata Raman to deliver his address on the "Spin of Light." Sir C. V. Raman in reply thanked the President for the kind words of welcome and said that it was a great privilege and pleasure to him to be present at the annual meeting of the Academy which consisted of so many distinguished scientists. Sir C. V. Raman then spoke on the "Spin of Light" (summary of the lecture is printed elsewhere).

Prof. André Weil of the Muslim University, Aligarh, proposed a hearty vote of thanks to the learned lecturer, and made a short speech eulogising his researches. Principal H. D. H. Drane seconded the vote of thanks in suitable terms and also thanked the University authorities for lending the Senate Hall for holding the annual meeting of the Academy.

LIST OF PAPERS READ BEFORE THE ACADEMY
OF SCIENCES DURING THE PERIOD FEBRUARY
1931 to MARCH 1932.

1. On the Colours of Inorganic Salts : *by Prof. M. N. Saha, F. R. S. and S. C. Deb, M.Sc., Physics Department, Allahabad University.*
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5. On the Absorption Spectra of Saturated Halides of Multivalent Elements : *by A. K. Dutta, M.Sc., and Prof. M. N. Saha, F. R. S., Department of Physics, Allahabad University.*
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7. Transactions of the Institution of Chemical Engineers. Vol. 8. 1930. (London)
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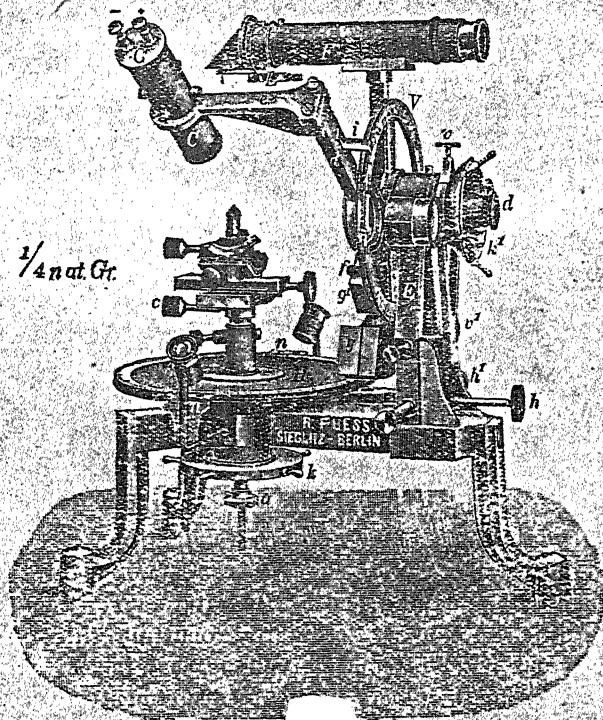
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